How to Service Radios with an Oscilloscope

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SYLVANIA ELECTRIC PRODUCTS INC.

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HOW TO SERVICE RADIOS WITH AN OSCILLOSCOPE

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PREFACE

The purpose of this book is to explain in a practical manner the operation and applications of the cathode ray oscilloscope. This is not an engineering manual. We expect that our readers will be radio and amplifier servicemen, and some radio operators, students and technicians.

Because of its general usefulness for all kinds of radio work, the oscilloscope deserves to be used much more widely than it is now. We believe that radio servicemen have neglected the oscilloscope more because of a lack of knowledge of how to use it than for any other single reason. This book explains in simple terms the steps to follow in using an oscilloscope to service AM and FM radios, audio amplifiers and transmitters. All theoretical material has been sifted, condensed and sifted again. Only absolutely essential theory—theory which we believe will be of real value to radio servicemen—has been retained. We have tried to keep the language as simple as possible and yet give complete and technically accurate explanations as well as detailed pictorial material to aid in a better understanding of the function of the oscilloscope.

Space in any book unfortunately is limited. There has not been room for every one of the thousands of applications of the oscilloscope. We have selected for complete explanation those applications which are most likely to be of interest and service to our readers. If we have been able, in any measure, to save radio servicemen time and trouble and make their tasks more interesting and enjoyable through better understanding and familiarity with new tools, we will consider our job not so badly done.

On the left is the Sylvania Three-Inch Oscilloscope Type 131 and on the right, the Sylvania Seven-Inch Oscilloscope Type 132. Use of these instruments in servicing AM and FM radio receivers and many other applications is described in detail in this book.

CHAPTER I

OSCILLOSCOPE FUNDAMENTALS

1.1 USEFULNESS OF THE OSCILLOSCOPE

The modern oscilloscope is the most useful single tool a radio repairman can own. More than any other instrument, it removes the guesswork from radio maintenance and repair and makes it possible to get at the seat of troubles quickly. Now moderately priced, oscilloscopes offer the exceptional advantage of allowing the serviceman to analyze the actual signal in radio circuits *while the circuits are in operation.*

The oscilloscope will:

1. Trace and measure a signal throughout the various rf, if, and audio channels of a receiver.
2. Indicate how well each channel is adjusted.
3. Reveal the presence of outside signal voltages, such as those due to hum and noise.
4. Check the operating characteristics of receiver audio channels and complete audio amplifiers by showing amplifier response patterns on its screen.
5. In the alignment of broad-band amplifiers and other circuits requiring special response curves, show the complete curve in one operation, thereby eliminating point-by-point plotting.
6. Perform a complete trouble-shooting job on a receiver or amplifier when used with a dc vacuum-tube voltmeter-ohmmeter, such as the Sylvania Polymeter; an audio oscillator, such as the Sylvania Type 145; and a signal generator such as the Sylvania Type 216.
7. Provide the *only* effective way of adjusting some types of modern radio apparatus, such as FM and television receivers, broad-band high-fidelity rf amplifiers, high-frequency power supplies, and automatic frequency control circuits.

Besides these applications the cathode ray oscilloscope can be used to observe other than electrical occurrences. Any mechanical changes which may be converted into corresponding voltage or current variations may be studied with an oscilloscope—as, for example, automobile engine performance or the behavior of sound waves.

1.2 CATHODE RAYS

Inasmuch as the cathode ray oscilloscope will occupy our attention throughout this book, it seems proper at the outset to describe *cathode rays* themselves, since they are the very foundation of all cathode ray apparatus.

In order to understand the nature of cathode rays, we must call to mind a simple vacuum tube of the type shown in Figure 1-1. In each end of an evacuated glass tube there is sealed an identical flat metallic plate provided with a wire lead extending through the tube. The two plates face each other. If one of these plates or *electrodes* is connected to the negative terminal of a high-voltage power supply (shown as a battery in Figure 1-1), this plate will become the *cathode* of the tube; the other plate, being connected to the positive high-voltage terminal, will become the anode.

Electrons will be drawn from the cathode as soon as the voltage is applied, and will pass through the tube to the anode. These electrons are negative particles. They are attracted by a high positive voltage and so always pass in a stream from cathode to anode. They constitute what we know as *cathode rays.* If we cut a small hole in the anode, the electrons move so fast that many of them will fly right through the hole, as shown in Figure 1-2. Cathode rays are invisible. However, if the inside wall of the right-hand end of the tube in Figure 1-2 is coated with a fluorescent

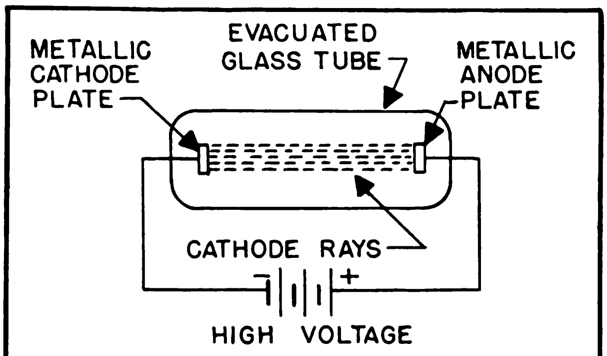


FIGURE 1-1 PRODUCTION OF CATHODE RAYS IN A SIMPLE VACUUM TUBE

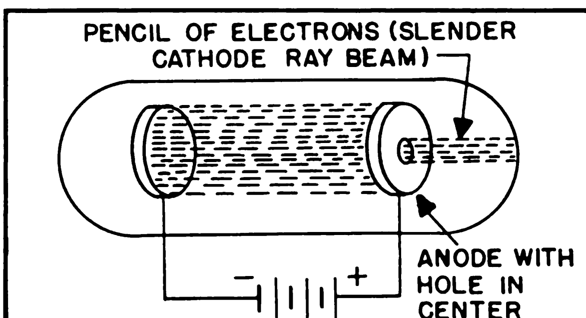


FIGURE 1-2 PRODUCTION OF CATHODE RAY BEAM BY MEANS OF A PERFORATED ANODE

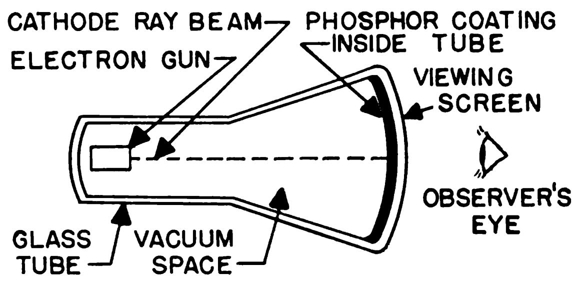


FIGURE 1-3 ARRANGEMENT OF GUN AND SCREEN IN OSCILLOSCOPE TUBE

chemical, it will glow at the point where the electron beam strikes it. This will produce a small, bright dot, at that point, but elsewhere the fluorescent surface will not be affected. In the modern oscilloscope tube employed by radio engineers and servicemen, emission of electrons is effected by heating a cathode, rather than as shown in Figures 1-1 and 1-2.

1.3 THE ELECTRON GUN

The heart of the oscilloscope tube is the *electron gun.* The electron gun is mounted in one end of the evacuated glass tube and projects its cathode ray beam toward the opposite end of the tube where the slightly curved glass end serves as a viewing screen. Minus other essential elements, the arrangement of the gun and viewing screen is shown in Figure 1-3.

The electron gun is not as simple a device as might be implied from an examination of Figure 1-3. A detailed cross sectional view of the commercial form of gun assembly is given in Figure 1-4. The electrons emitted by the heated cathode spread out in a cloud in all directions from the cathode surface, but are confined by the cylindrical *control electrode* (also known as Grid No. 1) which surrounds the cathode. The electrons may escape only through the small hole in the end disc of the control electrode. They emerge from this hole therefore in a narrow beam, as shown in Figure 1-4. This beam then passes successively through the cylindrical high voltage first accelerating electrode (Anode No. 1); the focusing electrode which is a center-holed disc, and then through the second accelerating electrode (Anode No. 2). (Sometimes both first and second sections of the accelerating anode are called "Anode No. 1.") The beam finally emerges from Anode No. 2 and proceeds down the center of the tube to the viewing screen.

The control electrode has the same sort of control over the electron flow from the cathode as does the control grid in a common radio tube. The number of electrons passing through the opening in the end disc of the control electrode is regulated by an adjustable negative voltage.

The electron beam is accelerated by Anode No. 1, since this electrode is operated at a positive voltage with respect to the cathode. The focusing electrode and Anode No. 2 are also operated at higher positive voltages. The three positively-charged anodes give the electrons considerable speed and concentrate the beam to a sharp point on the viewing screen at the other end of the cathode ray tube. When the voltages are low, the spot approaches the shape of a large splash of light with or without a surrounding halo. By adjusting these anode voltages, then, the spot may be focused on the screen. In actual practice, Anodes No. 1 and No. 2 usually are operated at a fixed high voltage, and focusing is achieved by adjusting the voltage applied to the focusing electrode. Brightness of the spot on the screen is governed by the value of negative voltage applied to the control electrode—the higher the negative bias the dimmer will be the spot on the screen. An external connection to this grid is brought out on the Sylvania Seven-Inch 'Scope for optional use in intensity modulation or "Z-axis" applications.

The voltages applied to the anodes are sufficiently high to be dangerous to the operator. Only under extreme conditions, should an oscilloscope ever be operated outside of its case, and then only by well-experienced personnel having more than usual knowledge of the circuit, applied voltage magnitudes, and

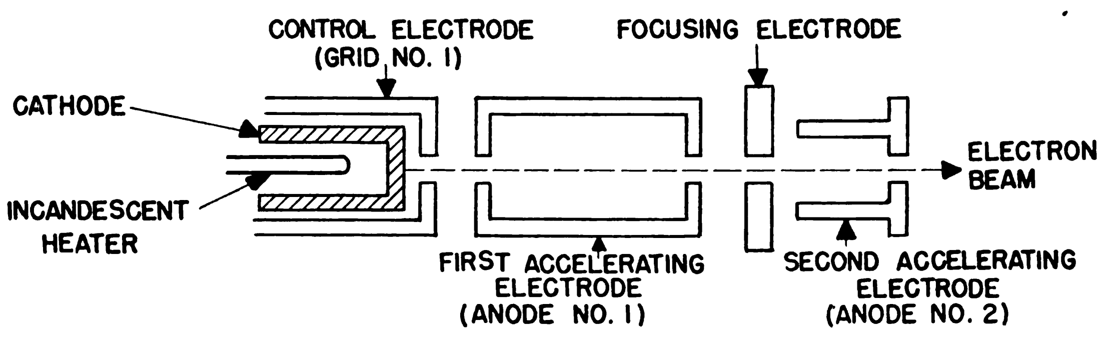


FIGURE 1-4 DETAILS OF A TYPICAL ELECTRON GUN

exposed high-potential points. Remember that inside the oscilloscope many points are connected to high voltages which in other electronic circuits are at low potential. For example, the chassis, normally "cold" in other types of instruments, is at —700 V. in the Sylvania 'Scope Type 131 and at —1500 V. in the Sylvania 'Scope Type 132.

1.4 DEFLECTING PLATES

If the tube had no other elements except the gun and screen, as indicated in Figure 1-3, the beam would strike the screen in the exact center and would produce a single glowing spot which might be focused. Such a tube would have little value for tests and measurements. To swing the beam around and move the spot to various positions on the screen *deflecting plates* are employed.

The placement of deflecting plates within a typical oscilloscope tube is shown in Figure 1-5. These metallic plates are arranged in pairs, with one pair at right angles to the other, so that the electron beam must pass successively between both pairs on its way to the fluorescent viewing screen and so come under the influence of any electric charge applied to the plates. One pair of plates (H_1 and H_2) is arranged to move the beam horizontally from side to side. The second pair (V_1 and V_2) moves the beam vertically, up and down. Figure 1-6 is an end view of a typical oscilloscope tube (looking in from the viewing screen end), showing the position of the two pairs of deflecting plates with respect to the electron beam.

If one remembers that a negative charge of high voltage will repel the electron beam and a positive charge will attract the beam he can understand how these electrostatic deflection plates work. Referring to Figure 1-6, if no external voltages are applied to either pair of deflecting plates, the beam will travel down the center of the tube and will produce a single spot on the screen. The screen pattern will then correspond to Figure 1-7(A).

If vertical plate V_1 is made positive with respect to vertical plate V_2, the beam will be attracted toward V_1, and the spot will be deflected upward away from

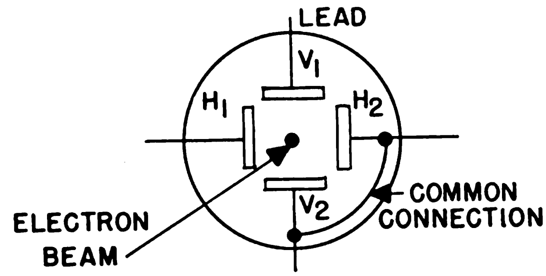


FIGURE 1-6 END VIEW OF A TYPICAL OSCILLOSCOPE TUBE, SHOWING ARRANGEMENT OF DEFLECTING PLATES

the center of the screen, as in Figure 1-7(B). If vertical plate V_1 is made negative with respect to V_2, the spot will be shifted downward, as in Figure 1-7(C). All three illustrations (A, B and C) assume that there is zero voltage on the horizontal deflecting plates (H_1 and H_2).

If the vertical plates are operated at zero voltage, and horizontal plate H_1 is made positive with respect to H_2, the beam will be attracted toward H_1, and the spot will be shifted to the left on the screen, as shown in Figure 1-7(D). And finally, if horizontal plate H_2 is made positive with respect to H_1, the spot will be shifted to the right on the screen, as shown in Figure 1-7(E).

In each instance, the distance the spot is moved from its center-of-screen (zero voltage) position is directly proportional to the applied voltage. If equal positive voltages are applied to vertical plate V_1 and horizontal plate H_1, the beam will be attracted both upward and to the left by equal forces. The result is a shift of the spot to a resultant position at a 45° angle from the center of the screen, as shown in Figure 1-7(F). Other combinations of voltages applied simultaneously to vertical and horizontal deflecting plates will shift the spot to corresponding positions on the screen. By choosing the proper horizontal and vertical voltages, the spot may be placed at any desired position on the screen.

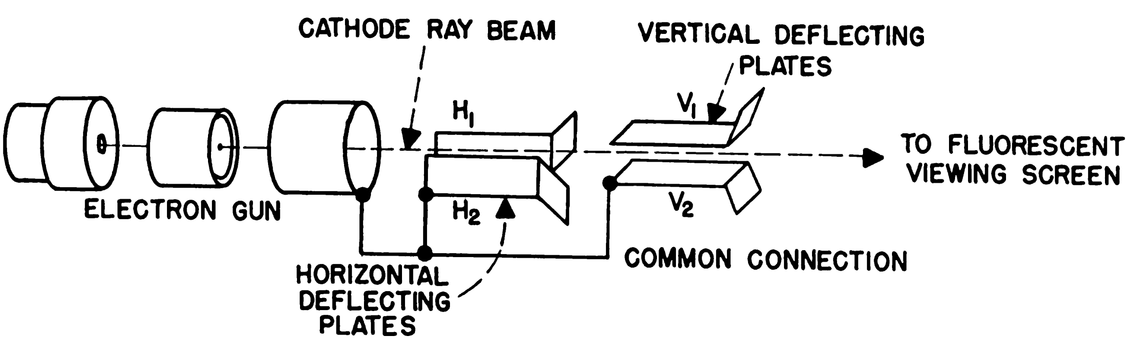


FIGURE 1-5 ARRANGEMENT OF ELECTRON GUN AND DEFLECTING PLATES IN A TYPICAL OSCILLOSCOPE TUBE

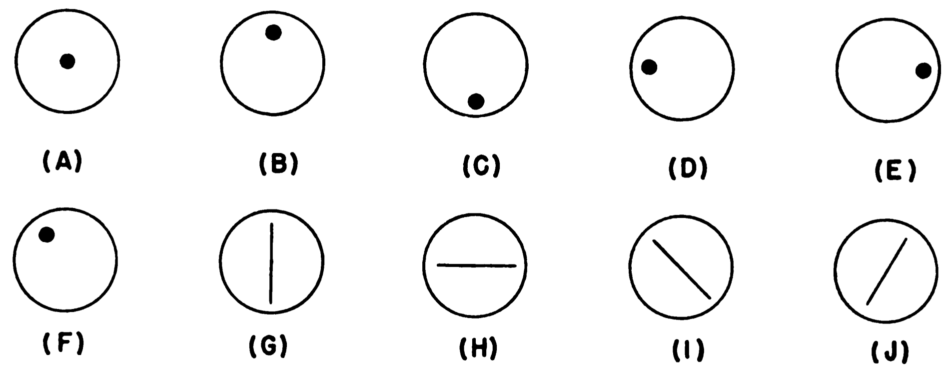


FIGURE 1-7 PATTERNS OBTAINED WITH VARIOUS VOLTAGES ON THE DEFLECTING PLATES

1.5 HOW AN AC SIGNAL AFFECTS THE BEAM

So far, we have discussed only direct voltages. But we have seen that the position of the spot serves to show whether the voltages have been applied to the horizontal or vertical plates or to both, and also that the distance through which the spot has moved away from the center of the screen is an indication of the amount of applied voltage. Also, the direction in which the spot moves from screen center indicates the polarity of the applied voltage. We know that alternating voltages, unlike the steady direct voltages just discussed, are constantly varying not only in value but also in polarity. We might expect, therefore, that alternating voltages applied to the deflecting plates will shift the spot to a large number of positions on the screen as the voltage goes through its positive and negative half-cycles. Let us now consider ac deflections.

If alternating voltage is applied to the two vertical deflection plates (V_1 and V_2), the spot will be moved rapidly up and down. The positive half-cycles will shift the spot from the center of the screen, upward and back to center. The negative half-cycles will shift the spot from center, downward and back to center. The distance the spot moves upward will depend upon the peak voltage reached during the positive half-cycle. Likewise, the downward displacement of the spot will depend upon the peak amplitude of the negative half-cycle. Most alternating voltages, unless distorted, go to as high a value on the positive side as on the negative. When a voltage of this sort is applied to the vertical deflecting plates, the spot is moved equal distances above and below the center of the screen.

When an alternating voltage is used, movement of the spot back and forth on the screen will be too rapid for the eye to follow. As a result of what is known as "persistence of vision" a vertical line will be seen (Figure 1-7(G)). Such a line is called a *trace* in oscilloscope practice. An alternating voltage applied to plates H_1 and H_2 will give the horizontal trace shown in Figure 1-7(H). If the same alternating voltage is applied at the same time to vertical plate V_1 and horizontal plate H_1, with the opposite "side" of the voltage applied to the common vertical-horizontal connection, the vertical and horizontal deflections will rise and fall in step, the cathode ray beam will be swung back and forth by equal vertical and horizontal forces, and the trace will assume a position 45° between vertical and horizontal, as shown in Figure 1-7(I). When the alternating voltages are applied to plates V_1 and H_2, the 45° trace will be on the opposite side of the vertical center line of the screen, as shown in Figure 1-7(J).

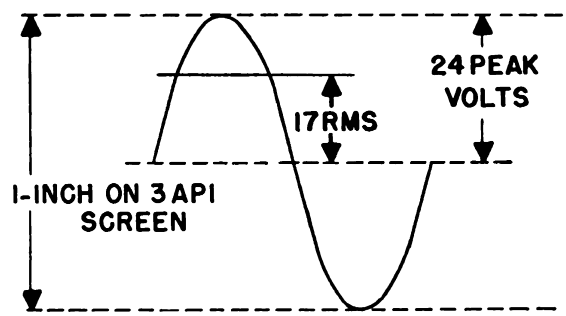


FIGURE 1-8 SCREEN SENSITIVITY OF SYLVANIA TYPE 3AP1 OSCILLOSCOPE TUBE

The length of the ac traces is directly proportional to the alternating voltage peak value. The angle of the traces shown in Figures 1-7(I) and 1-7(J) depends upon the ratio of the two applied alternating voltage values.

1.6 SENSITIVITY

Sensitivity of a cathode ray tube is rated in terms of the signal voltage required to shift the spot one inch on the screen. It is assumed in making this statement that the signal voltage is applied directly to the deflecting plates without any amplifications. The sensitivity figure is given in rms volts-per-inch ***peak to peak*** when an alternating voltage is employed, and

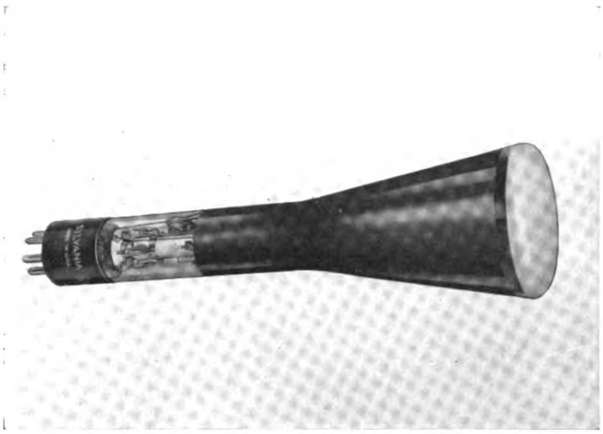


FIGURE 1-9 Sylvania 3AP1 Cathode Ray Tube used in the Sylvania Oscilloscope Type 131.

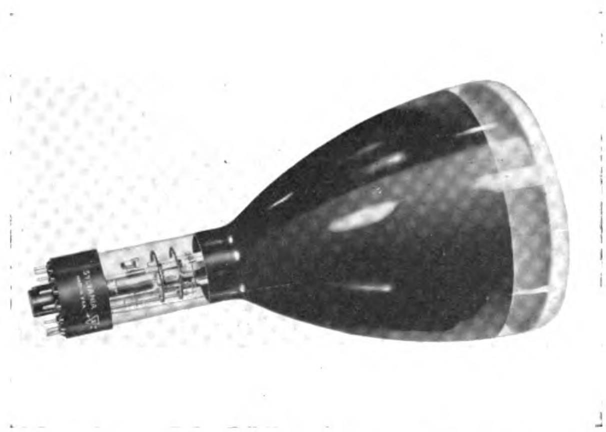


FIGURE 1-10 Sylvania 7GP1 Cathode Ray Tube used in the Sylvania Oscilloscope Type 132.

simply in volts-per-inch when the applied signal is a direct voltage. Sensitivity of the Sylvania Type 3AP1 tube, as used in the Sylvania Oscilloscope Type 131, is 17 volts rms to give a one inch peak to peak deflection. That is, an ac voltage 17 volts rms on an ordinary voltmeter will produce a trace which measures one inch from the top of the positive peak to the bottom of the negative peak on a 3AP1 tube screen. See Figure 1-8.

1.7 CATHODE RAY TUBE SIZES

Oscilloscope tubes are rated in size according to the diameters of their viewing screens. Thus, the three inch tube has a three inch viewing screen, the seven inch tube a seven inch diameter screen, etc.

Study and experience in all problems involved show the three and seven inch diameters to be the most practical and versatile oscilloscope tube sizes for general laboratory and radio shop applications. These diameters give good clear images large enough to be seen easily. They also provide good sensitivity. Figures 1-9 and 1-10 are pictures of popular oscilloscope tubes of these two sizes. Figure 1-9 shows the Sylvania Type 3AP1 three-inch tube. Figure 1-10 shows the Sylvania Type 7GP1 seven-inch tube, used in the Sylvania Oscilloscope Type 132.

CHAPTER II

THE LINEAR TIME BASE

2.1 FUNCTION OF TIME BASE

Up to this point, we have considered only the patterns obtained when signal voltages are applied to the deflecting plates of an oscilloscope tube. The oscilloscope finds its greatest use, however, in observation of the actual waveform and amplitude of alternating and transient voltages.

On graphs of such voltages, amplitude (measured vertically) is always plotted against time (measured horizontally). Examples are the 60-cycle sine wave shown in Figure 2-1(A) and the 60-cycle square wave shown in Figure 2-1(B). In each case, voltage level (amplitude) is shown along the vertical axis and time along the horizontal axis.

To reproduce waveforms on the viewing screen, it is necessary to *sweep* the spot across the screen horizontally from left to right at the same time that the spot is being moved up and down vertically by the signal voltage under observation. Furthermore in order to carry out this process successfully, a complete left-to-right sweep of the electron beam must be accomplished in the time required for the vertical signal to complete one cycle, if we wish to see one complete cycle on the screen.

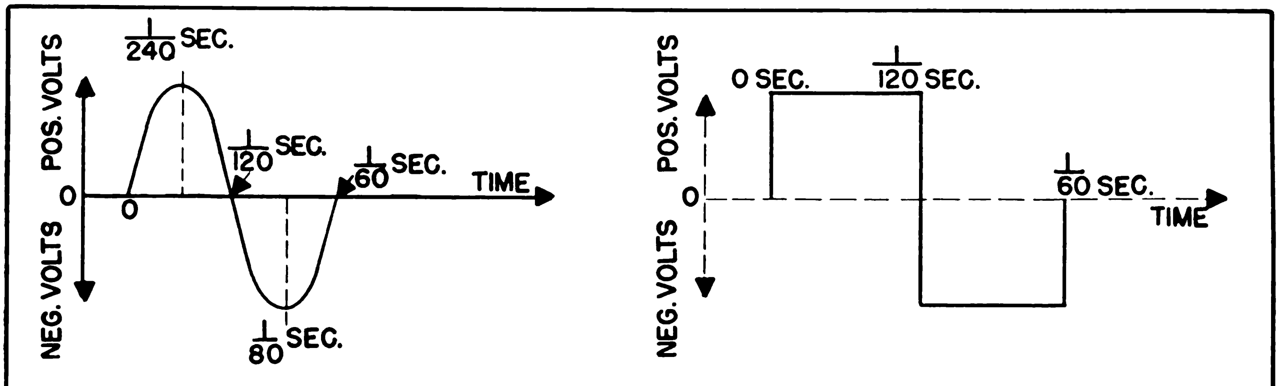
In Figure 2-1(A), when a 60-cycle sine wave signal voltage is applied to the vertical plates and a left-to-right linear sweeping voltage is applied to the horizontal plates, the spot traces out a plot of the voltage variations occurring in one cycle of the signal voltage. Thus, the spot will start its trip at zero, will be at the crest of the positive half-cycle in 1/240 second, at the zero line at 1/120 second, at the trough of the negative half-cycle at 1/80 second, and again at the zero line 1/60 second from the time it started. In between these time intervals, the spot will be at each point along the curve and will move with such speed as to give instantaneous reproduction of the waveform.

2.2 SWEEP VOLTAGE NATURE AND SOURCE

In order to sweep the electron beam horizontally in one direction only (left to right), the sweep voltage must be made to increase evenly from zero to a positive value high enough to shift the spot to the extreme right-hand side of the screen, and then must fall suddenly to zero.

If no signal is applied to the vertical plates, the horizontal trace produced by the sweep voltage will be a straight line, similar to that shown in Figure 1-7(H). Although any alternating voltage applied to the horizontal plates will produce such a straight line trace, sine waves are unsatisfactory as normal time bases since they do not possess the desirable feature of an even (linear) rise in voltage from zero to a high positive value and almost instantaneous return to zero.

A suitable waveform for the time-base sweep voltage is shown in Figure 2-2. Note that this sawtooth-shaped voltage wave successively rises evenly from E_1 (zero) to E_2 (the positive value required to shift the spot to the right-hand side of the screen) and



(A) SINE WAVE (B) ONE TYPE OF SQUARE WAVE

FIGURE 2-1 RELATION OF VOLTAGE VARIATIONS TO TIME

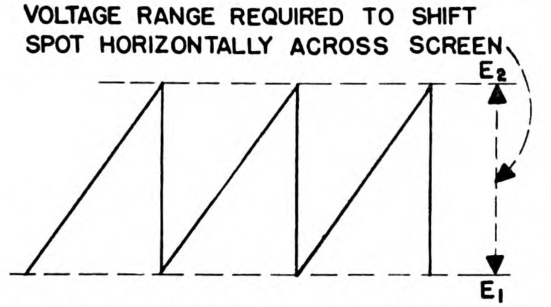


FIGURE 2-2 SAWTOOTH SWEEP VOLTAGE APPLIED TO HORIZONTAL PLATES

then falls quickly back to level E_1. The sharp drop from E_2 to E_1 must occur in a small fraction of the time required for the completion of one cycle of the signal voltage applied to the vertical plates.

The required sawtooth wave may be generated by any one of a number of special circuits. However, the circuit usually employed in oscilloscopes is a relaxation-type gaseous tube oscillator. The circuits of the linear sweep oscillator employed in the Sylvania Three-Inch Oscilloscope Type 131 is shown in Figure 2-3. A similar circuit is used in the Type 132 seven-inch instrument.

In this circuit, the sawtooth waveform is generated by the alternate charging of one of the capacitors selected by switch S_2 and the subsequent discharge of the capacitor through the Type 884 gaseous triode. The mechanism may be explained in this manner: Current flows from the 300-volt dc power source into the capacitor, causing the voltage across the capacitor to build up as shown by the climbing sides of the wave in Figure 2-2. When the capacitor voltage reaches a certain value, the tube fires, quickly discharging the capacitor. This discharge causes the capacitor voltage to drop quickly, as indicated by the steep dropping sides of the wave in Figure 2-2. The tube stops conducting when the capacitor voltage falls to the "extinction potential" of the tube. The capacitor then recharges from the 300-volt source, and the sawtooth is repeated. The frequency of the sawtooth oscillation is governed by the capacitance of the selected capacitor and the resistance setting of the potentiometer R_2. Actually, the capacitor sets the frequency *range* in this circuit, and R_2 may be set to secure any desired frequency within this range. Because of this action, switch S_2 is termed the COARSE FREQUENCY CONTROL, and potentiometer R_2, the FINE FREQUENCY CONTROL. C_1 in the Sylvania Oscilloscope Type 131 is the 0.25 μfd capacitor which selects the 15-90 cycle sweep frequency range. With S_2 in its C_1 position the potentiometer R_2 accordingly is "tunable" from 15 to 90 cycles. The frequency range of the sweep-voltage generator contained in the Sylvania Oscilloscope Type 131 extends from 15 to 40,000 cycles per second. The Type 132 has a range of approximately 15 to 30,000 cycles per second.

Sawtooth output voltage from the plate circuit of the sweep oscillator is coupled to the horizontal input circuit of the oscilloscope tube. Since this output voltage usually is too low to be effective, and since the sweep oscillator should be isolated from the rest of the instrument circuit, a voltage amplifier (not shown in Figure 2-3) is inserted between the sweep oscillator and the horizontal deflecting plates. This amplifier will be discussed later.

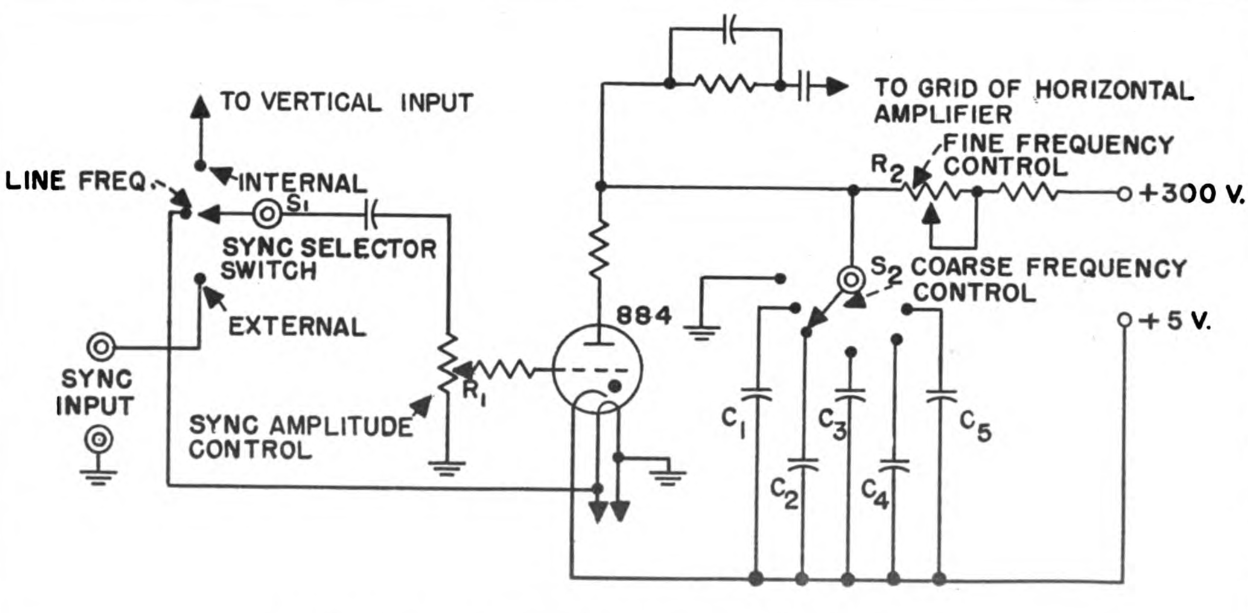


FIGURE 2-3 SAWTOOTH LINEAR SWEEP OSCILLATOR

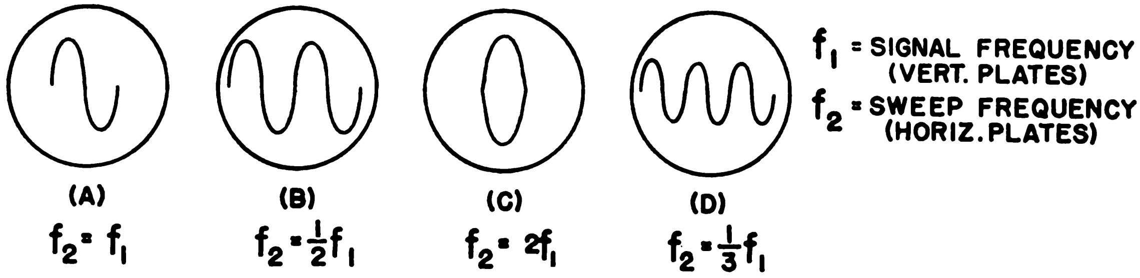


FIGURE 2-4 SIGNAL VS. SWEEP RELATIONS AS VIEWED ON OSCILLOSCOPE SCREEN

The sweep oscillator is self-excited. However, if it is to show one cycle of signal voltage on the screen, it must oscillate at the same frequency as the signal under test. If two test cycles are to be shown on the screen, it must oscillate at one half the frequency of the test signal, etc. To do either it must be synchronized with a signal voltage to keep their frequencies "locked together" to prevent the pattern from drifting across the screen. This synchronizing voltage is applied to the grid of the sweep oscillator tube. The same signal voltage which is applied to the vertical deflecting plates can be applied also to the grid of the 884 tube when S_1, the SYNC SELECTOR SWITCH (see Figure 2-3), is thrown to its INTERNAL position. Internal synchronization allows the signal to "freeze" its own pattern on the screen. This removes the necessity of supplying a separate synchronizing signal. When S_1 is in its lowermost (EXTERNAL) position, any suitable *external* signal voltage may be fed into the instrument for synchronizing purposes, via the SYNC terminals. When switch S_1 is set to its center (LINE FREQUENCY) position, the synchronizing voltage, taken from the 884 heater terminals, has the same frequency as that of the power line. Proper adjustment of the SYNC AMPLITUDE CONTROL potentiometer, R_1, locks the image in a stationary position on the screen. Advancing this control beyond the setting where the pattern stops distorts the waveform.

2.3 SWEEP AND SIGNAL VOLTAGE RELATIONS

When the sawtooth sweep voltage has the same frequency as that of the vertical signal voltage, it has been shown that a single complete cycle of signal voltage appears on the screen. This pattern is shown in Figure 2-4(A). When the sweep frequency is one-half the signal frequency, the signal has a chance to complete two cycles by the time the sweep trace reaches the right-hand side of the screen. The corresponding pattern is shown in Figure 2-4(B). If the sweep frequency is twice the signal frequency, the horizontal swing is completed at the end of the positive half-cycle of the signal. The beam then swings back to the left-hand side of the screen and starts out again. This second swing then catches the negative half-cycle, plotting it directly below the positive half, as shown in Figure 2-4(C). A sweep frequency equal to one-third the signal frequency will catch three complete cycles of the signal, as shown in Figure 2-4(D).

From these relationships, it is clear that by proper adjustment of the sweep frequency controls the serviceman can select one or several cycles of signal voltage for study on the screen. While sine waves have been shown here for the sake of simplicity, use of the instrument is not restricted to sine wave signals. The patterns might as easily have been those of more complex waves.

CHAPTER III

THE COMPLETE OSCILLOSCOPE

3.1 INSTRUMENT ARRANGEMENT

In the foregoing chapters, to explain how an oscilloscope works, we have talked about the cathode ray tube and its operation almost as if this tube were all by itself. To fit it for tests and measurements, however, the tube requires, in addition to a power supply and sweep oscillator, already described, several other circuits and devices. The complete oscilloscope, such as the Sylvania Type 131 Three-Inch and the Type 132 Seven-Inch, is a complex instrument of many stages.

Several "basic oscilloscopes" are likewise available. The basic instrument is composed simply of a cathode ray tube and power supply. Such an oscilloscope is limited in application, since no provision is made in its circuit for sweep action or for signal amplification. The incomplete, basic oscilloscope was designed primarily for use as a modulation meter for radiophone stations, and is useful for very little else. It has virtually no value in radio servicing.

A block diagram of a typical complete oscilloscope is given in Figure 3-1. This diagram shows the arrangement of the various controls, switches, and circuits which comprise the complete instrument, and indicates their relationship to each other. These sections of the instrument will be discussed separately in the following paragraphs.

Vertical Amplifier. This is a high gain *broad-band* voltage amplifier, used to increase the signal voltage applied to the vertical deflecting plates. Without this amplifier, low signal voltages could not be examined, since they do not produce a vertical trace on the screen of sufficient height. The vertical amplifier is provided with a gain control in order that the serviceman can adjust the amount of amplification. Setting of the vertical gain control governs the height of the pattern on the viewing screen.

The input circuit of the amplifier is coupled to the VERTICAL INPUT terminal through a fixed capacitor which serves also to protect the instrument from any harmful dc voltage in the signal under measurement.

Vertical Amplifier Switch. This is the single-pole, double-throw switch, S_1, in Figure 3-1. When this

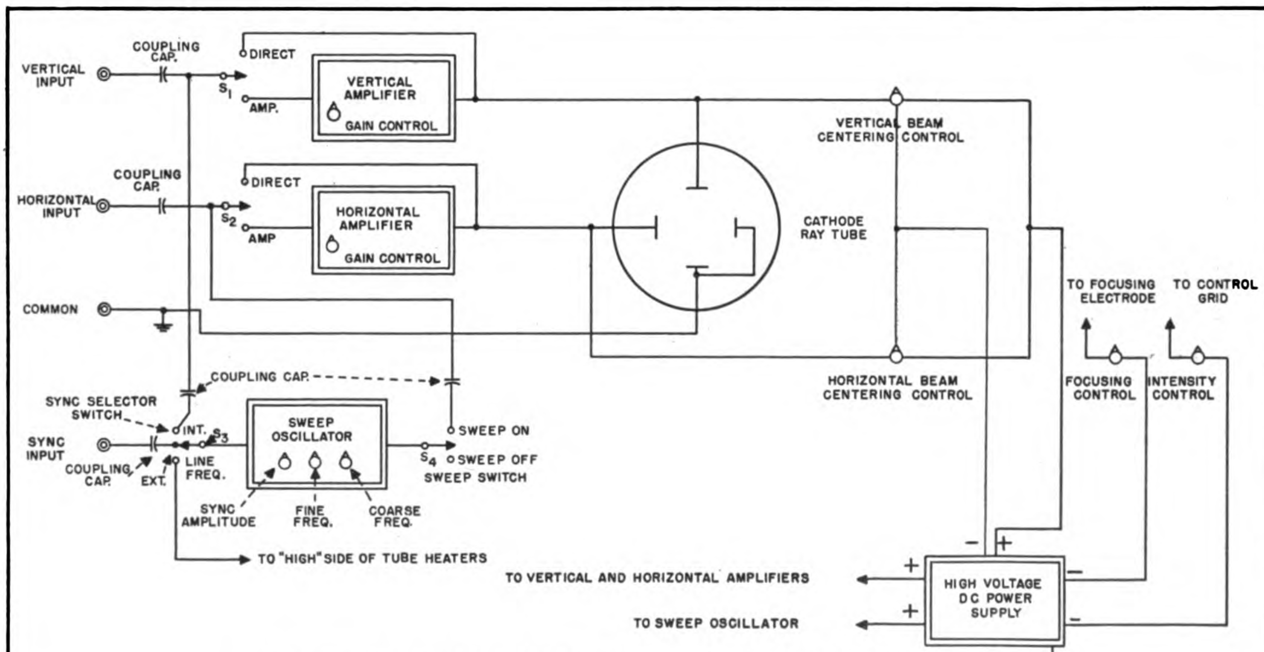


FIGURE 3-1 BLOCK DIAGRAM OF COMPLETE OSCILLOSCOPE

switch is thrown to its upper position, the signal is applied directly to the vertical deflecting plates. A large signal voltage, or one outside the frequency range of the vertical amplifier, may be handled in this manner. When S_1 is thrown to its lower position, the signal is passed through the amplifier before going to the vertical plates. The vertical amplifier switch, S_1, is known also by the name of "signal input switch."

Horizontal Amplifier. Like the vertical amplifier, this is a high gain voltage amplifier. The purpose of this stage is to increase the signal voltage applied to the horizontal deflecting plates. Without this amplifier, a low signal voltage (including the output voltage of the linear sweep oscillator) might not produce a sufficiently long trace on the viewing screen. Like the vertical amplifier, the horizontal amplifier is provided with a gain control, and is coupled through a fixed isolating capacitor to the HORIZONTAL INPUT terminal.

Because of its usual function in the complete oscilloscope, the horizontal amplifier frequently has been termed the "sweep amplifier" or "time base amplifier."

Horizontal Amplifier Switch. This is the single-pole, double-throw switch, S_2, in Figure 3-1. It works in the same way as the vertical amplifier switch, S_1. That is, when the horizontal switch is thrown to its lower position the signal or sweep voltage goes to the horizontal amplifier for intensification before being applied to the horizontal deflecting plates.

Sweep Oscillator. The sweep oscillator in this instrument set-up is the relaxation-type sawtooth wave generator described previously in Section 2.2 and represented in Figure 3-1 by the lower left-hand block. This unit is provided with controls for SYNC AMPLITUDE, COARSE FREQUENCY adjustment, and FINE FREQUENCY adjustment, each of which was described in Section 2.2 and shown in detail in Figure 2-3. The sweep oscillator has the main function of sweeping the signal across the screen so that it will appear on the scope in the same form as it occurs in the circuit being tested. The sweep oscillator may also be used in frequency comparisons and other applications to be described further along in this book.

Sweep Switch. When sweep switch, S_4, is set to its lower position, no sweeping voltage is coupled from the plate circuit of the sawtooth oscillator to the horizontal deflecting plates. When S_4 is thrown to its upper position, however, the sweep oscillator output is capacitively coupled to the cathode ray circuit. (On the two Sylvania oscilloscopes, the sweep switch is incorporated in the COARSE FREQUENCY control. When this coarse frequency control is moved to the "off" position, the sweeping voltage is eliminated. In any other position the coarse frequency control couples the sweep voltage to the cathode ray circuit.) With S_4 in its upper position, and the horizontal amplifier switch, S_2, thrown to DIRECT, the sweep voltage is applied directly to the horizontal plates. When S_2 is thrown to AMP, the sweep voltage is amplified by the horizontal amplifier and then applied to the horizontal deflecting plates. The width of the horizontal trace, and accordingly the width of any pattern on the viewing screen, may be adjusted by means of the setting of the gain control in the horizontal amplifier, when S_2 is thrown to AMP.

Sync Selector Switch. By means of the sync selector switch, S_3, the proper synchronizing voltage may be selected and applied to the sweep oscillator grid. As was shown in Section 2.2, the switch allows the operator to look at one or more complete cycles of test signal, shown motionless on the screen. A portion of the test signal itself may be used to lock the sweep oscillator to its frequency (INT. position of switch). An external oscillator or signal source can also be used to synchronize the sweep oscillator with the test signal EXT. position of switch, or the test signal can be synchronized by the line voltage frequency (LINE FREQ. position of switch).

Beam Centering Controls. These potentiometers enable the operator to place the spot on any part of the viewing screen. The spot may be moved up and down, from top to bottom of the screen by means of the vertical beam centering control, or back and forth, from one side of the screen to the other, by means of the horizontal beam centering control. The two controls are high-resistance potentiometers through which continuously variable dc voltages of the proper polarity are applied to the deflecting plates. The range of beam centering adjustment is wide enough to permit the moving of the spot to any position, and even entirely off the screen in any direction.

Intensity Control. The intensity or brilliance control is a potentiometer through which a continuously variable dc voltage of negative polarity is applied to the control grid of the cathode ray tube to regulate the brightness of the image on the screen. The higher the voltage delivered by this control, the dimmer will be the image.

In order to prevent burning of the viewing screen, the serviceman should use at all times the minimum intensity which will give a pattern which may easily be seen. For the same reason, bright stationary patterns must not be held on the screen for long periods. Keep the pattern in motion whenever possible. A single bright dot is especially harmful to the screen.

Focusing Control. The focusing control is a potentiometer through which a continuously variable dc voltage of positive polarity is applied to the focusing electrode of the cathode ray tube to regulate clarity of the image on the screen. The range of the control is wide enough to allow adjustment of spot size from a tiny clear pin-point to a large splatter surrounded by a fuzzy halo. When the focusing control is set properly, the trace or image on the screen has sharp, clear lines, well in focus. When focusing is incorrect, the lines of the image will be thick and fuzzy and accurate readings of heights and widths on the screen are impossible.

Power Supply. The high-voltage dc power supply

furnishes electrode voltage for the cathode ray tube, horizontal and vertical amplifier tubes and sweep oscillator tube. Tube heater voltages come from one or more low-voltage secondary windings on the power supply transformer. The power supply of an oscilloscope is not the same as the power stage of a radio receiver, transmitter, or other test instrument. The transformer, for example, is designed to have a low-level and restricted hum field, in order to prevent modulation of the trace on the screen. Iron-core choke coils are not usually used in the output filter for the same reason. Instead, resistance capacitance filters are ordinarily employed to smooth out the output voltage ripple. The power supply must include a high voltage circuit, in order to provide the high dc voltage required by the cathode ray tube anodes. A lower voltage power supply provides the anode and screen voltages for the horizontal and vertical amplifier stages.

Common Input Terminal. The input terminal marked COMMON in Figure 3-1 receives the "low-side" of all signal input voltages—vertical, horizontal or sync. The use of this common terminal simplifies the drawing but most complete oscilloscopes provide separate *ground* or *low* terminals for the vertical and horizontal amplifiers and for the synchronizing voltage input. Otherwise it would be necessary to insert many wire leads into this one terminal post.

3.2 SYLVANIA OSCILLOSCOPE TYPE 131

The schematic circuit of a specific complete oscilloscope is given in Figure 3-2. This is the wiring diagram of the Sylvania Type 131 three-inch instrument. An interior photograph of the oscilloscope appears in Figure 3-6; an external view in the frontispiece of this book.

Vertical and Horizontal Amplifiers. In this instrument, both vertical and horizontal amplifier tubes (V-101 and V-102 respectively) are Type 7C7 Lock-In pentodes. R-102 and R-115 are corresponding vertical and horizontal amplifier gain controls—or *height* and *width* controls. Note that separate ground terminals are provided in the Oscilloscope Type 131 for both vertical and horizontal signal inputs, instead of the single common terminals shown in Figure 3-1. Either one of these ground terminals may be used in conjunction with the EXT SYNC terminals or with the 6.3 volt ac terminal.

Vertical and Horizontal Amplifier Switches. S-103 and S-104 are respectively the vertical and horizontal amplifier switches. When these switches are thrown to their upper position, input signals are applied directly to the deflecting plates of the Type 3AP1 oscilloscope tube (V-104). When they are thrown to their lower position, the vertical and horizontal signals pass first through the corresponding amplifiers and are intensified.

In the Oscilloscope Type 131, the vertical amplifier switch, S-103, is attached to the vertical gain control, R-102. This switch is thrown automatically to its upper (DIRECT) position when the vertical gain control is set to the extreme left-hand (OFF) position. The horizontal amplifier switch, S-104, is attached to the horizontal gain control, R-115, and is thrown to its upper (DIRECT) position automatically when the horizontal gain control is set to its extreme left-hand position.

Sweep Oscillator. The sawtooth linear sweep oscillator, described in Section 2.2, is built around the Type 884 gaseous triode, V-103.

Sweep Switch. The sweep switch is contained in the COARSE FREQUENCY control, S-102. When this control is in "off" position, the sweep oscillator is switched off. In other positions of the coarse frequency control the sweep oscillator output is coupled to the cathode ray tube circuit.

Sync Selector Switch. S-101 is the sync selector switch, described in Section 3.1. With it the serviceman can choose to synchronize the sweep oscillator with an external signal (EXT.), a line frequency signal (LINE FREQ.) or a portion of the same signal that goes to the vertical deflecting plates (INT.).

Coarse Frequency Control. As has been mentioned in Section 2.2, the COARSE FREQ. control is the six position switch S-102. In its five "on" positions it selects from five separate values of capacitance (C-116 to C-120), which govern the frequency ranges of the sweep oscillator. These five ranges are: 15-90 cycles, 90-500 cycles, 500-2,500 cycles, 2.5-10 kilocycles, and 10-40 kilocycles, and are so labeled on the front panel.

Fine Frequency Control. The potentiometer R-126 is the fine frequency control. It regulates the frequency of the sweep oscillator within each of the five ranges selected by the coarse frequency control. For example, if the COARSE FREQ. switch is set to 15-90, the FINE FREQ. control will then permit selection of any frequency between 15 cycles and 90 cycles.

Sync Amplitude Control. The potentiometer, R-123, is the sync amplitude control. Rotating this control clockwise increases the amplitude of the synchronizing signal applied to the grid of the 884 sweep oscillator tube, V-103, and holds a pattern stationary on the screen. Advancing the control beyond the setting where the pattern stops, distorts the waveform.

Beam Centering Controls. The vertical beam centering control is potentiometer R-105 and the horizontal beam centering control is potentiometer R-106.

Focusing Control. Potentiometer R-111 is the focusing control which varies the voltage on the focusing electrode of the cathode ray tube.

Intensity Control. Potentiometer R-113 is the intensity control. It varies the negative voltage on the control grid of the cathode ray tube.

Line Switch. The ON-OFF power line switch, S-105, is attached to the intensity control and is thrown to its OFF position when this control is set to its extreme left-hand (zero brilliance) position.

Power Supply. The dual power supply is made up of tubes V-105 (Type 7Y4) and V-106 (Type 5Y3GT/G), and a resistance-capacitance ripple filter.

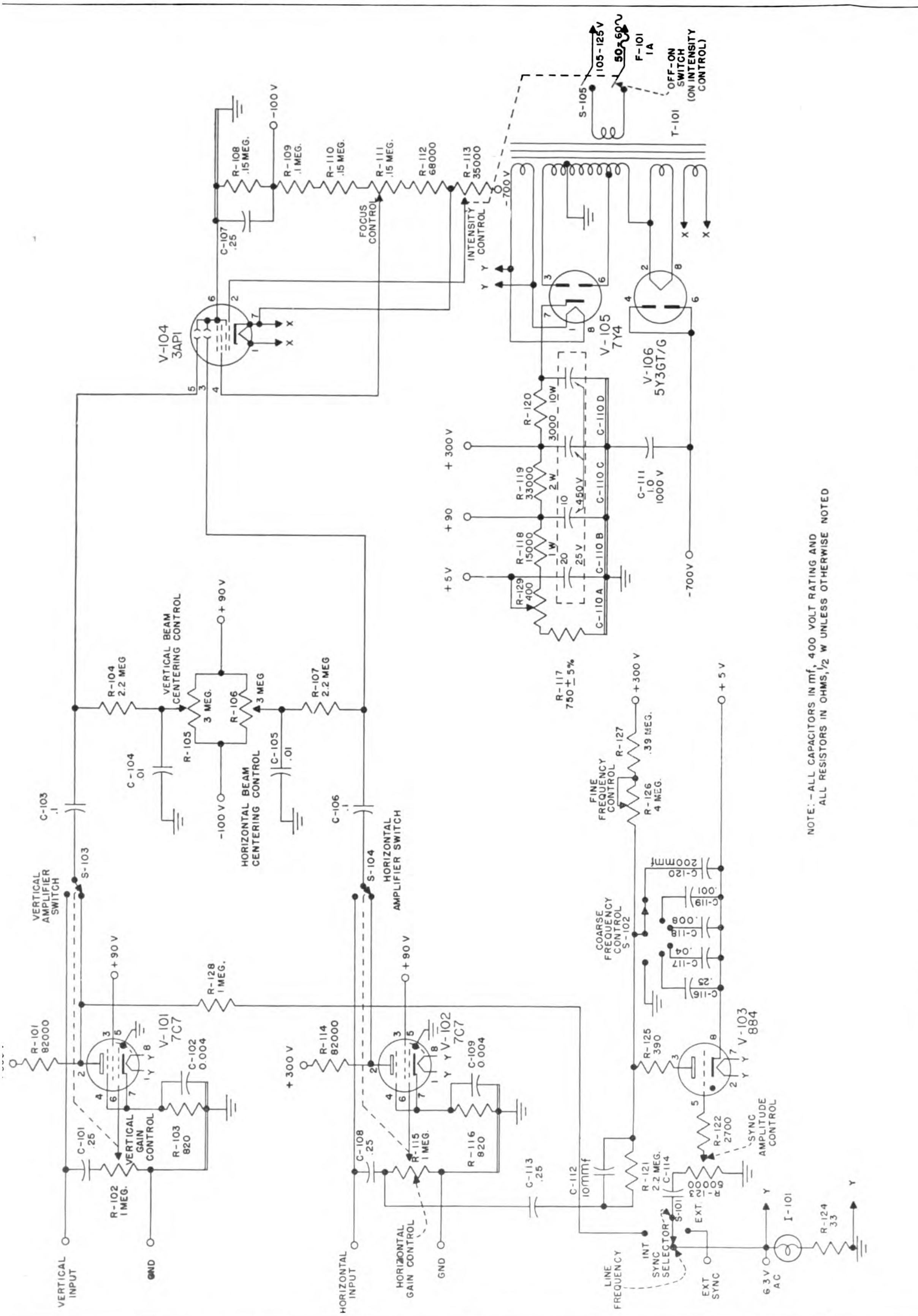


FIGURE 3-2 SCHEMATIC CIRCUIT - SYLVANIA OSCILLOSCOPE TYPE 131

SYMBOL	DESCRIPTION	RATING	TOL %	SYLVANIA PART NO.
C-101	Condenser, Tubular Paper	0.25 uf., 400V	+30 -20	Pc. 13103
C-102	Condenser, Tubular Paper	0.004 uf., 400 V.	+20 -10	Pc. 13740
C-103	Condenser, Tubular Paper	0.1 uf., 400 V.	+30 -20	Pc. 12796
C-104	Condenser, Tubular Paper	0.01 uf., 400 V.	+30 -20	Pc. 13098
C-105	Same as C-104			
C-106	Same as C-103			
C-107	Same as C-101			
C-108	Same as C-101			
C-109	Same as C-102			
C-110	Condenser, Can Type Electrolytic	10-10-10/20 uf. 450/25 V.		Pc. 12784
C-111	Condenser, Can Type Paper	1.0 uf., 1000 V.		Pc. 12785
C-112	Condenser, Mica	10 uuf., 500 V.	±10	Pc. 13095
C-113	Same as C-101			
C-114	Same as C-103			
C-116	Condenser, Tubular Paper	0.25 uf., 400 V.	±20	Pc. 13100
C-117	Condenser, Tubular Paper	0.04 uf., 400 V.	±20	Pc. 13099
C-118	Condenser, Tubular Paper	0.008 uf., 400 V.	±20	Pc. 13101
C-119	Condenser, Mica	1000 uuf., 500 V.	±10	Pc. 13097
C-120	Condenser, Ceramic	200 uuf., 500 V.	±10	Pc. 13315
F-101	Fuse, Type 3AG	1 Ampere		Pc. 2422
I-101	Lamp-Incandescent Bayonet S-47	6-8 V., 0.15 A.		Pc. 2828
R-101	Resistor-Composition	82,000 ohms, ½ W.	±10	Pc. 1020
R-102	Resistor-Variable, linear taper	1 meg., 1/3 W.	±20	Pc. 12791
R-103	Resistor-Composition	820 ohms, ½ W.	±10	Pc. 936
R-104	Resistor-Composition	2.2 meg., ½ W.	±10	Pc. 1080
R-105	Resistor-Variable, linear taper	3 meg., 1/3 W.	±20	Pc. 12792
R-106	Same as R-105			
R-107	Same as R-104			
R-108	Resistor-Composition	0.15 meg., ½ W.	±10	Pc. 1031
R-109	Resistor-Composition	0.1 meg., ½ W.	±10	Pc. 1024
R-110	Same as R-108			
R-111	Resistor-Variable, linear taper	0.15 meg., 1/3 W.	±20	Pc. 12790
R-112	Resistor-Composition	68,000 ohms, ½ W.	±10	Pc. 1017
R-113	Resistor-Variable, linear taper	35,000 ohms, 1/3W	±20	Pc. 12788
R-114	Same as R-101			
R-115	Same as R-102			
R-116	Same as R-103			
R-117	Resistor-Composition	750 ohms, ½ W.	± 5	Pc. 935
R-118	Resistor-Composition	15,000 ohms, 1 W.	±10	Pc. 1244
R-119	Resistor-Composition	33,000 ohms. 2 W.	±10	Pc. 1513
R-120	Resistor-Wire Wound	3000 ohms, 10 W.	± 5	Pc. 12787
R-121	Same as R-104			
R-122	Resistor-Composition	27,000 ohms, ½ W.	±10	Pc. 999
R-123	Resistor-Variable, Audio taper	50,000 ohms, ½ W.	±20	Pc. 12789
R-124	Resistor-Composition	33 ohms, ½ W.	±10	Pc. 877
R-125	Resistor-Composition	390 ohms, ½ W.	±10	Pc. 922
R-126	Resistor-Variable, linear taper	4 meg., 1/3 W.	±20	Pc. 12941
R-127	Resistor-Composition	0.39 meg., ½ W.	±10	Pc. 1048
R-128	Resistor-Composition	1.0 meg., ½ W.	±10	Pc. 1066
R-129	Resistor-Adjustable wire wound	400 ohms	± 5	Pc. 11925
S-101	Switch-Rotary, S.P., 3T Non-shorting			Pc. 12650
S-102	Switch-Rotary, D.P., 6T Non-shorting			Pc. 12515
S-103	Switch-Variable Resistor Mounting S.P. 2T			
S-104	Switch-Variable Resistor Mounting S.P. 2T			
S-105	Switch-Variable Resistor Mounting 2P S.T.			
V-101	Tube, Sylvania Type 7C7			
V-102	Same as V-101			
V-103	Tube, Sylvania Type 884			
V-104	Tube, Sylvania Type 3AP1			
V-105	Tube, Sylvania Type 7Y4			
V-106	Tube, Sylvania Type 5Y3GT/G			

FIGURE 3-3- PARTS LIST - SYLVANIA 3-inch OSCILLOSCOPE TYPE 131

A 6.3 volt ac output terminal is provided for test purposes. This is very useful. A lead may be run directly from this terminal to the vertical input terminal to check operation of the oscilloscope at the power line frequency. This 6.3 volt source may also be used in place of an oscillator to supply a signal for any tests in which a 60-cycle (or other line frequency) signal will be satisfactory. The 6.3 volt source will deliver 0.3 amperes and therefore may be used to power the filament or heater in other instruments, such as a simple test oscillator or clipper-type square wave generator.

Location of Controls. The following controls and terminals are located on the front panel of the Sylvania Oscilloscope Type 131: vertical beam centering, horizontal beam centering, focus control, intensity control, vertical gain, horizontal gain, sync amplitude, coarse frequency, fine frequency, sync selector, external sync terminal, vertical input terminal, horizontal input terminal, 6.3 volt ac terminal, two ground terminals, and pilot light. There are no controls or terminals in the rear of this instrument.

Viewing Screen. For purpose of accurate measurements of the pattern along both horizontal and vertical axes, Sylvania Oscilloscope Type 131 is provided with a transparent overlay disc ruled-off in vertical and horizontal coordinate lines. The Type 131 screen has 30 vertical and 30 horizontal lines, with each fifth line heavier than the others. The scope is also provided with a light hood which reduces the glare on the screen due to room lighting.

Characteristics. Input impedance of the vertical amplifier is 1 megohm and 30 μμf when gain control R-102 is advanced to maximum. Input impedance when switch S-103 is thrown for direct connection to the vertical deflecting plates is 680,000 ohms and 45 μμf.

Input impedance of the horizontal amplifier is 1 megohm and 50 μμf when gain control R-115 is advanced to maximum. Input impedance when switch S-104 is thrown for direct connection to the horizontal deflecting plates is 680,000 ohms and 60 μμf.

Sine-wave frequency response of the vertical and horizontal amplifiers is uniform within 3 db from 10 cycles to 100 kilocycles. This range is sufficiently wide for all radio and PA amplifier servicing applications.

The sensitivity of the Type 131 Oscilloscope is such that using the amplifiers, 0.5 volt rms will give a 1-inch peak-to-peak deflection on the screen; and without the amplifiers (direct signal input to the deflecting plates), 17 volts rms will give a 1-inch peak-to-peak deflection. (See Figure 1-8.)

The linear sweep frequency is continuously variable in 5 ranges between 15 and 40,000 cycles. The sweep direction is from left to right.

3.3 SYLVANIA OSCILLOSCOPE TYPE 132

The schematic circuit of a larger, complete oscilloscope is given in Figure 3-4. This is the wiring diagram of the Sylvania Type 132 seven-inch instrument. This circuit will be seen to be more complicated than that of the three-inch oscilloscope described in Section 3.2. An interior photograph of this oscilloscope appears in Figure 3-7; an external view may be seen in the frontispiece of this book. The sections of the Type 132 instrument will be described in the following paragraphs.

Vertical and Horizontal Amplifiers. In the Type 132 Oscilloscope, both vertical and horizontal amplifiers are phase-inverter type push-pull amplifiers. The vertical amplifier employs two Type 7C7 tubes (V-101 and V-102); the horizontal amplifier also employs two Type 7C7 tubes (V-103 and V-104). R-101 and R-114 are the corresponding gain control potentiometers.

The amplifiers are coupled to the VERTICAL and HORIZONTAL INPUT terminals by means of 1000-volt capacitors (C-101 and C-109).

Vertical Amplifier Switch. This is the double-pole, double-throw switch, S-101, located at the back of the scope. Its two positions are marked plainly DIRECT and AMP. See Figures 3-8 and 3-9. When the poles of this switch are thrown to their upper position, the signal is applied directly to the vertical deflecting plates through input terminals provided at the back. A high amplitude signal, or one which is outside of the frequency range of the vertical amplifier, may be handled with the switch in this position. When the poles of S-101 are thrown to their lower position, the signal is passed through the push-pull vertical amplifier before being presented to the vertical plates.

Horizontal Amplifier Switch. This is the double-pole, double-throw switch, S-102. This switch likewise is located on the rear of the Sylvania Seven-Inch Oscilloscope. Its positions are marked plainly, DIRECT and AMP. When the poles of this switch are thrown to their upper position, the signal is applied directly to the horizontal deflecting plates through input terminals on the back of the instrument. A high amplitude signal, or one which is outside of the frequency range of the horizontal amplifier, may be handled with the switch in this position. When the poles of S-102 are thrown to their lower position, the signal is passed through the push-pull horizontal amplifier before being presented to the horizontal deflecting plates.

Sweep Oscillator. The sweep oscillator is a relaxation-type sawtooth wave generator similar to the one described previously in Section 2.2. This unit is provided with controls for SYNC AMPLITUDE, COARSE FREQUENCY adjustment, and FINE FREQUENCY adjustment. The sweep oscillator tube is V-105 (Type 884).

Sweep Switch. The sweep switch is incorporated in the COARSE FREQUENCY control, S-104. When this switch is in "off" position, the sweep oscillator is switched off. In other positions, the coarse frequency control couples the sweep oscillator output to the cathode ray circuit.

Sync Selector Switch. By means of the sync switch, S-103, the proper synchronizing voltage may be selected and applied to the sweep oscillator grid. When

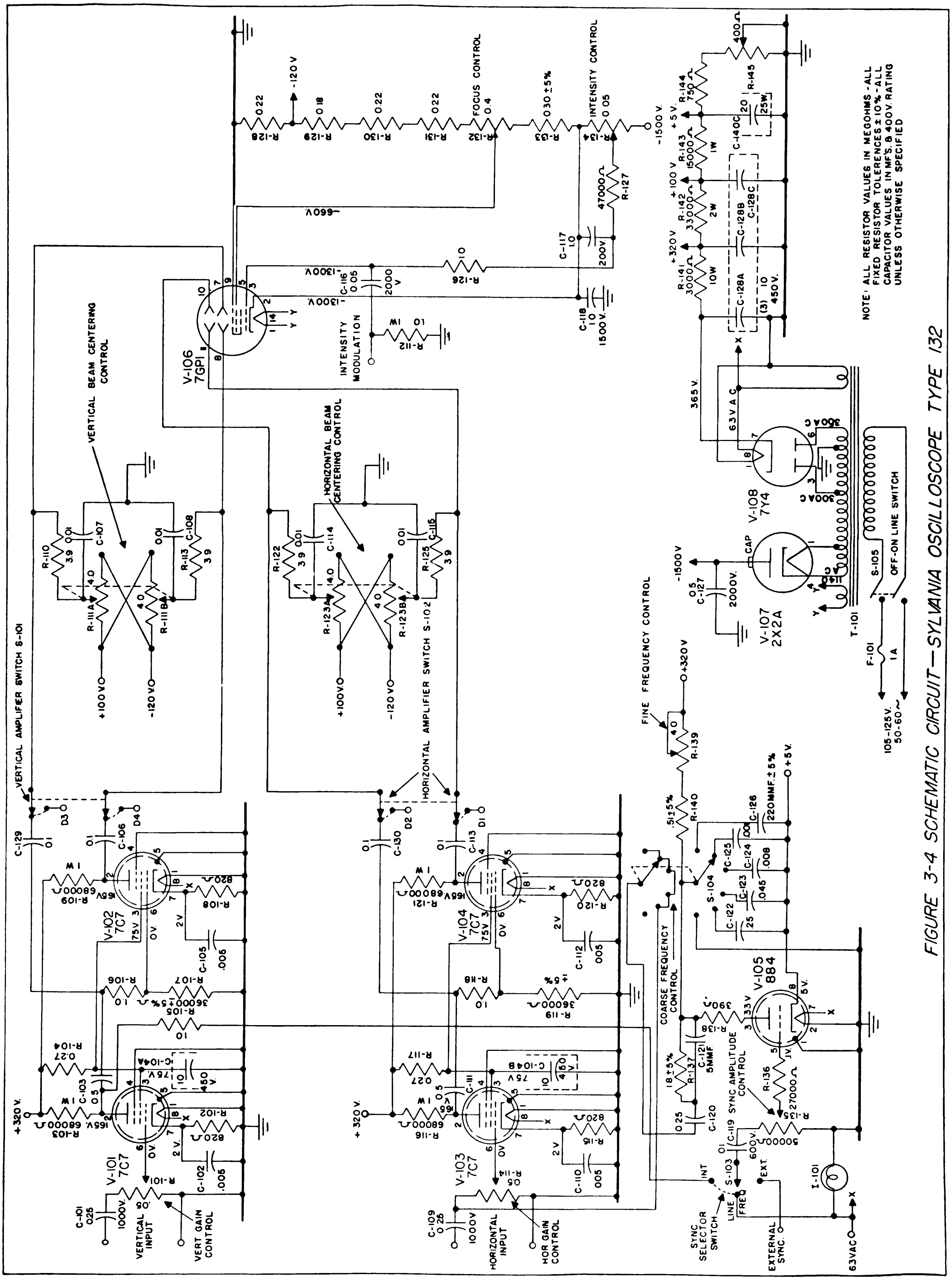


FIGURE 3-4 SCHEMATIC CIRCUIT—SYLVANIA OSCILLOSCOPE TYPE 132

SYMBOL	DESCRIPTION	RATING	TOL %	SYLVANIA PART NO.
C-101	Condenser, Tubular Paper	0.25 mf., 1000V.	+20 -10	Pc. 14987
C-102	Condenser, Tubular Paper	0.005 mf., 400V.	+20 -10	Pc. 16163
C-103	Condenser, Tubular Paper	0.5 mf., 400V.	+30 -10	Pc. 12800
C-104	Condenser, Tubular Electrolytic	10-10/20 mf., 450/25V.		Pc. 16378
C-105	Same as C-102			
C-106	Condenser, Tubular Paper	0.1 mf., 400V.	+30 -10	Pc. 12796
C-107	Condenser, Tubular Paper	0.01 mf., 400V.	+30 -10	Pc. 12794
C-108	Same as C-107			
C-109	Same as C-101			
C-110	Same as C-102			
C-111	Same as C-103			
C-112	Same as C-102			
C-113	Same as C-106			
C-114	Same as C-107			
C-115	Same as C-107			
C-116	Condenser, Tubular Paper	0.05 mf., 2000V.	+30 -10	Pc. 16424
C-117	Condenser, Tubular Paper	1.0 mf., 200V.	+30 -10	Pc. 16377
C-118	Condenser, Can Type Paper	1.0 mf., 1500V.	+20 -10	Pc. 16172
C-119	Condenser, Tubular Paper	0.1 mf., 600V.	+20 -10	Pc. 16168
C-120	Condenser, Tubular Paper	0.25 mf., 400V.	+30 -10	Pc. 12798
C-121	Condenser, Tubular Ceramic	5 mmf., 500V.	±10	Pc. 16161
C-122	Condenser, Tubular Paper	0.25 mf., 400V.	±10	Pc. 16169
C-123	Condenser, Tubular Paper	0.045 mf., 400V.	±10	Pc. 16982
C-124	Condenser, Tubular Paper	0.008 mf., 400V.	±10	Pc. 16164
C-125	Condenser, Mica	0.001 mf., 500V.	±10	Pc. 15401
C-126	Condenser, Mica	220 mmf., 500V.	±10	Pc. 16162
C-127	Condenser, Can Type Paper	0.5 mf., 2000V.	+20 -10	Pc. 16873
C-128	Condenser, Can Type Electrolytic	10-10-10 mf., 450V.		Pc. 16173
C-129	Same as C-106			
C-130	Same as C-106			
F-101	Fuse, Type 3AG	1 Ampere		Pc. 2422
I-101	Lamp-Incandescent Bayonet S-47	6-8V., 0.15 A.		Pc. 2828
R-101	Resistor-Variable, linear taper	0.5 meg., ¼ W.	±20	Pc. 16391
R-102	Resistor-Composition	820 ohms, ½ W.	±10	Pc. 936
R-103	Resistor-Composition	68,000 ohms, 1 W.	±10	Pc. 1272
R-104	Resistor-Composition	0.27 meg., ½ W.	±10	Pc. 1041
R-105	Resistor-Composition	1.0 meg., ½ W.	±10	Pc. 1066
R-106	Same as R-105			
R-107	Resistor-Composition	36,000 ohms, ½ W.	± 5	Pc. 1005
R-108	Same as R-102			
R-109	Same as R-103			
R-110	Resistor-Composition	3.9 meg., ½ W.	±10	Pc. 1090
R-111	Resistor-Variable, linear taper	Dual 4 meg., ¼ W.	±20	Pc. 16393
R-112	Resistor-Composition	1.0 meg., 1 W.	±10	Pc. 1321
R-113	Same as R-110			
R-114	Same as R-101			
R-115	Same as R-102			
R-116	Same as R-103			
R-117	Same as R-104			
R-118	Same as R-105			
R-119	Same as R-107			
R-120	Same as R-102			
R-121	Same as R-103			
R-122	Same as R-110			
R-123	Same as R-111			
R-125	Same as R-110			
R-126	Same as R-105			

FIGURE 3-5 PARTS LIST - SYLVANIA 7-inch OSCILLOSCOPE TYPE 132

SYMBOL	DESCRIPTION	RATING	TOL %	SYLVANIA PART NO.
R-127	Resistor-Composition	47,000 ohms, ½ W.	±10	Pc. 1010
R-128	Resistor-Composition	0.22 meg., ½ W.	±10	Pc. 1038
R-129	Resistor-Composition	0.18 meg., ½ W.	±10	Pc. 1034
R-130	Same as R-128			
R-131	Same as R-128			
R-132	Resistor-Variable, linear taper	0.4 meg., 2 W.	±10	Pc. 16157
R-133	Resistor-Composition	0.3 meg., ½ W.	± 5	Pc. 1043
R-134	Resistor-Variable, linear taper	50,000 ohms, 1/3 W.	±20	Pc. 16155
R-135	Resistor-Variable, linear taper	50,000 ohms, ¼ W.	±20	Pc. 16390
R-136	Resistor-Composition	27,000 ohms, ½ W.	±10	Pc. 999
R-137	Resistor-Composition	1.8 meg., ½ W.	± 5	Pc. 1076
R-138	Resistor-Composition	390 ohms, ½ W.	±10	Pc. 922
R-139	Resistor-Variable, linear taper	4 meg., ¼ W.	±20	Pc. 16392
R-140	Resistor-Composition	0.51 meg., ½ W.	± 5	Pc. 1054
R-141	Resistor-Wire Wound	3000 ohms, 10 W.	± 5	Pc. 12787
R-142	Resistor-Composition	33,000 ohms, 2 W.	±10	Pc. 1513
R-143	Resistor-Composition	15,000 ohms, 1 W.	±10	Pc. 1244
R-144	Resistor-Composition	750 ohms, ½ W.	± 5	Pc. 935
R-145	Resistor-Variable, linear taper	400 ohms, 1 W.	±10	Pc. 16154
S-101	Switch-Slide, DPDT			Pc. 16429
S-102	Same as S-101			
S-103	Switch-Rotary, S.P. 3T Non-shorting			Pc. 16810
S-104	Switch-Rotary, D.P. 6T Non-shorting			Pc. 12515
S-105	Switch-Toggle, D.P.S.T.			Pc. 15011
V-101	Tube, Sylvania Type 7C7			
V-102	Same as V-101			
V-103	Same as V-101			
V-104	Same as V-101			
V-105	Tube, Sylvania Type 884			
V-106	Tube, Sylvania Type 7GP1			
V-107	Tube, Sylvania Type 2X2A			
V-108	Tube, Sylvania Type 7Y4			

FIGURE 3-5 PARTS LIST - SYLVANIA 7-inch OSCILLOSCOPE TYPE 132

S-103 is thrown to its upper (INTERNAL) position, the synchronizing voltage, obtained through series resistor R-105, is the same signal voltage which is applied to the vertical deflecting plates. Applying the signal simultaneously to the vertical plates and sync input results in self-synchronization. When S-103 is thrown to its center (LINE FREQ) position, synchronizing voltage is obtained from one leg of the sweep tube heater, and accordingly has the same frequency as the power-line voltage. When S-103 is thrown to its lower (EXTERNAL) position, a synchronizing voltage may be obtained, through coupling capacitor C-110, from an external oscillator (or other suitable signal source) connected to the SYNC INPUT terminal.

Coarse Frequency Control. As has been mentioned in Section 2.2, the coarse frequency control is the six-position switch S-104. In its five "on" positions it selects from five separate values of capacitance (C-122 to C-126), which govern the frequency range of the sweep oscillator. These five ranges are 15-90 cycles, 90-500 cycles, 500-2,500 cycles, 2.5-10 kilocycles, and 10-30 kilocycles, and are so labeled on the front panel.

Fine Frequency Control. The potentiometer R-139 is the fine frequency control. It regulates the frequency of the sweep oscillator within each of the five ranges selected by the coarse frequency control. For example, if the coarse frequency switch is set to 15-90, the fine frequency control will then permit selection of any frequency between 15 cycles and 90 cycles.

Sync Amplitude Control. The potentiometer R-135 is the sync amplitude control. Rotating this control clockwise increases the amplitude of the synchronizing signal applied to the grid of the 884 sweep oscillator tube (V-103) and holds a pattern stationary on the screen. Advancing the control beyond the setting where the pattern stops, distorts the waveforms.

Beam Centering Controls. As in the Type 131 three-inch oscilloscope, the beam centering controls in the Type 132 instrument enable the operator to position the spot on any part of the viewing screen. Thus, by means of these two controls (R-111A and R-111B for vertical centering, and R-123A and R-123B for horizontal centering), a normally off-center spot, peculiar to a particular oscilloscope tube, may be brought to the exact center of the screen. In the Type 132 instrument, each beam centering control consists of two "gang-tuned" potentiometers, as may be seen in Figure 3-4.

Focus Control. Potentiometer R-132 is the focus

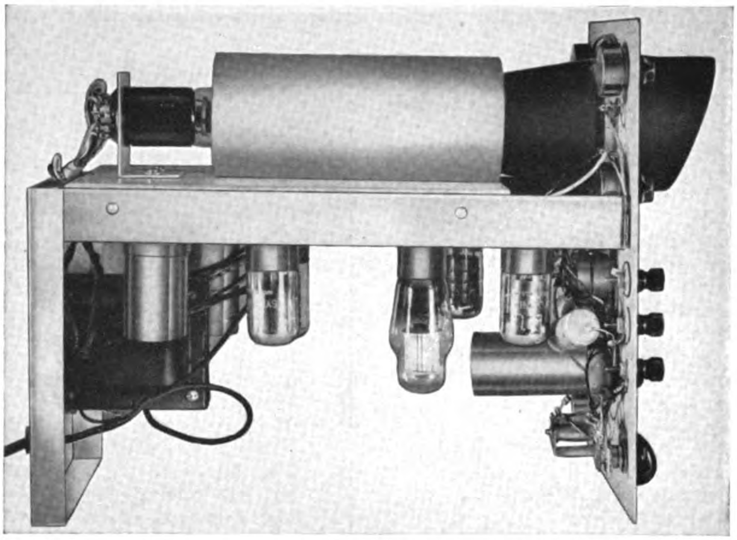


FIGURE 3-6 Inside view of Sylvania Three-Inch Oscilloscope Type 131. Note large metal shield around neck of tube. Tubes and other circuit components are mounted below 3AP1 tube. Power transformer (lower left) is mounted as far as possible from tube to prevent hum modulation of electron beam.

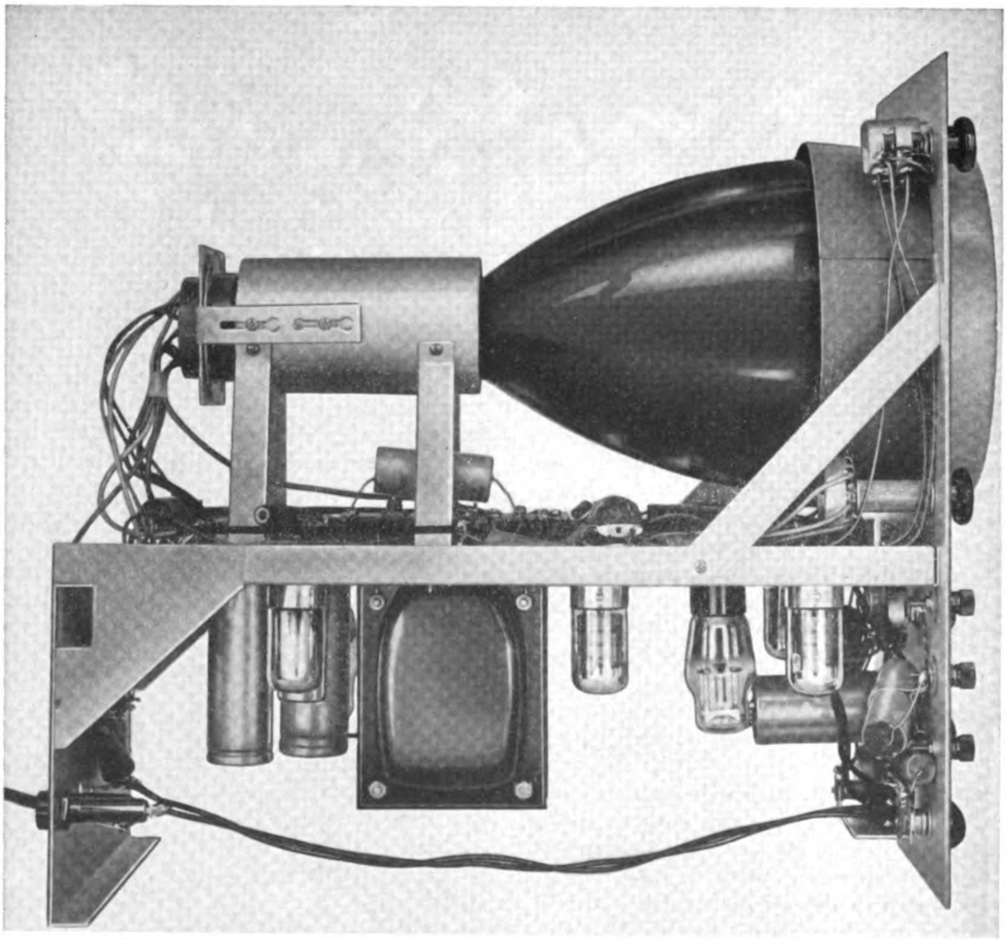


FIGURE 3-7 Inside view of Sylvania Seven-Inch Oscilloscope Type 132. Construction is similar to that of Type 131 three-inch instrument except that higher voltage components and larger tubes are necessary. Circuit is also more complicated. (See Figure 3-4).

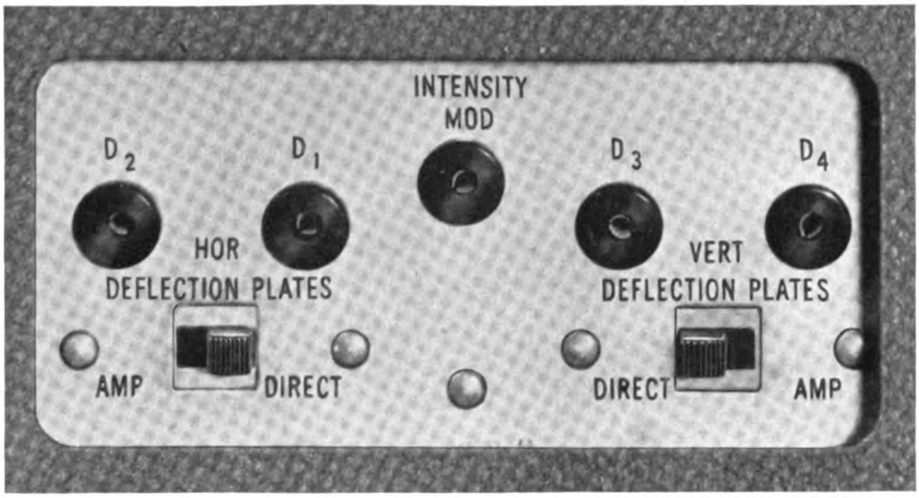


FIGURE 3-8 Rear panel of Sylvania Seven-Inch Oscilloscope Type 132. This panel contains the horizontal and vertical amplifier switches and input jacks for the deflecting plates and intensity modulations. (See Figure 3-9 for a graphic explanation of panel jacks and switches.)

control which varies the high positive voltage on the first anode of the cathode ray tube.

Intensity Control. The potentiometer R-134 (see Figure 3-4) is the intensity control. It varies the negative bias on the control grid of the cathode ray tube.

Line Switch. The "on-off" power line switch is the front panel toggle switch, labeled S-105 on the circuit diagram.

Intensity Modulation Input. A tip jack is available on the rear terminal panel of the instrument (see Figures 3-8 and 3-9) for introducing an externally-generated signal voltage to modulate the control grid of the Type 7GP1 cathode ray tube. This type of modulation varies the brightness of the spot on the viewing screen in accordance with the modulation, and thus may be utilized to blank out undesired portions of the trace. It may be employed also to provide "timing dots" to time the length of a wave under observation on the screen. Methods of using intensity modulation will be described in a later chapter.

Power Supply. The dual high-voltage power supply of the Type 132 oscilloscope is composed of rectifier tubes V-107 (Type 2X2A) and V-108 (Type 7Y4) and a multisection resistance-capacitance ripple filter.

Location of Controls. The seven-inch oscilloscope has the following controls and terminals on its front panel: vertical beam centering, horizontal beam centering, focus control, intensity control, vertical gain, horizontal gain, sync amplitude, coarse frequency, fine frequency, sync selector, external sync terminal, 6.3 volt ac terminal, two ground terminals, pilot light and ON-OFF toggle switch for the power line. The rear

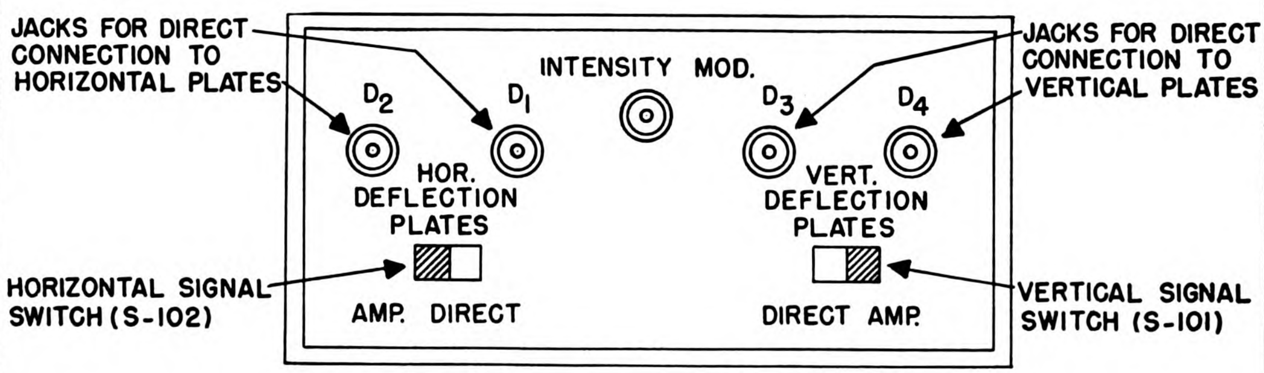


FIGURE 3-9 REAR PANEL OF TYPE 132, SHOWING PINJACKS AND SWITCHES (SEE ALSO FIGURE 3-8)

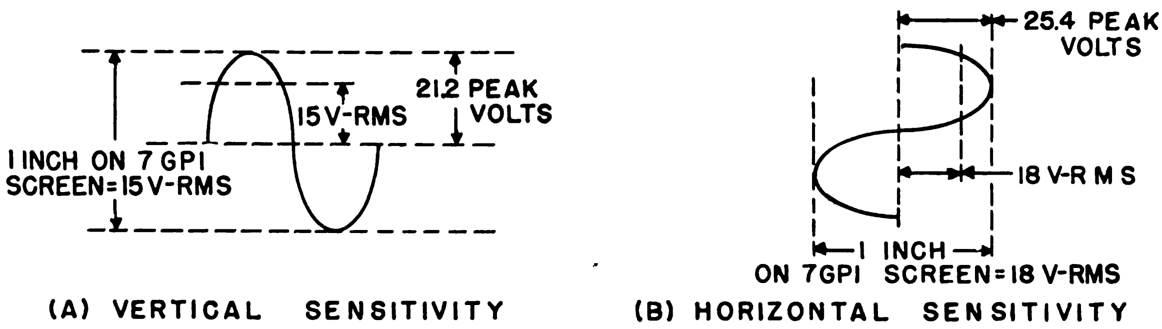


FIGURE 3-10 SCREEN SENSITIVITY OF SYLVANIA TYPE 7GP1 OSCILLOSCOPE TUBE

panel has four tip-type jacks for direct input to the deflecting plates, one tip-jack for intensity modulation input and the vertical and horizontal amplifier switches.

Viewing Screen. To make accurate measurements of waveforms easier, the Sylvania Oscilloscope Type 132 is provided with a transparent overlay disc ruled off in vertical and horizontal coordinate lines. There are 60 horizontal and 60 vertical lines with each tenth line accentuated. It is made of ¼″ safety glass.

Characteristics. Input impedance of the vertical amplifier corresponds to 0.5 megohm and 26 μμf. Input impedance, when the vertical signal switch, S-101, is thrown for direct connection to the vertical deflecting plates, corresponds to 3.9 megohms and 20 μμf between each deflecting plate terminal and chassis ground.

Input impedance of the horizontal amplifier corresponds to 0.5 megohm and 33 μμf. Input impedance, when the horizontal signal switch, S-102, is thrown for direct connection to the horizontal deflecting plates, corresponds to 3.9 megohms and 20 μμf between each deflecting plate terminal and chassis ground.

Sine-wave frequency response of the vertical amplifier is within ±20% (1000-cycle reference) from 10 cycles to 70 kilocycles. Response is down not more than 30% at 7 cycles and at 90 kc, and is down not more than 50% at 145 kc.

Sine wave frequency response of the horizontal amplifier is within ±20% (1000-cycle reference) from 10 cycles to 55 kc. Response is down not more than 30% at 7 cycles and at 75 kc, and is down not more than 50% at 135 kc.

The sensitivity of the Type 132 oscilloscope is such that with the vertical amplifier, 0.21 volts rms sine wave will give a 1-inch peak-to-peak deflection on the viewing screen; and without the vertical amplifier, a 15 volt rms sine-wave signal will be required for a 1-inch peak-to-peak deflection on the screen. With the horizontal amplifier, a 0.25 volt rms sine-wave signal will give a 1-inch peak-to-peak deflection; and without the horizontal amplifier, 18 volts rms sine wave will be required to give a 1-inch peak-to-peak deflection. (See Figure 3-10.)

The linear sweep frequency is continuously variable in 5 ranges, from 15 to 30,000 cycles. The sweep direction is from left to right.

CHAPTER IV

VOLTAGE MEASUREMENT WITH THE OSCILLOSCOPE

4.1 CATHODE RAY TUBE AS V.T. VOLTMETER

The cathode ray tube is a voltage-operated device, since deflection of its electron beam is accomplished by means of applied voltages. In many of its applications, the oscilloscope actually functions as a highly specialized electronic ac voltmeter, although we may interpret its indications in other terms. Both horizontal and vertical deflection are proportional to the instantaneous applied horizontal and vertical signal voltage amplitudes. These voltage values may be determined by measuring the length of the traces they produce, provided the viewing screen is calibrated. The length of the trace on the viewing screen (or movement of the spot over a screen distance) increases linearly with applied voltage—a distinct advantage in any voltmeter. The oscilloscope also has a high impedance input circuit which keeps at a minimum any loading of a circuit under test. Unlike the nearest comparable voltmeter, which can indicate only voltage *amplitude* under a recommended set of operating conditions, the oscilloscope can show waveform and phase relations, positive and negative amplitudes without limitations as to waveform or distortion, and with fewer limitations as to frequency.

Because it is so useful, modern laboratories strongly encourage the use of the oscilloscope in ac voltage measurements and in tests of various sorts in which other changes can be translated into voltage variations. In some voltage measurements, the oscilloscope is indispensable. In other such measurements, it is better to employ a regular voltmeter. For example, it is hardly possible that a radio repairman would demand an oscilloscope for measuring the heater voltage unless no simpler ac voltmeter were available. But he would prefer to use the oscilloscope if a test required that the voltage measuring instrument have higher input impedance, better sensitivity, and better frequency response than his ac voltmeter of the amplifier type. The oscilloscope constitutes an excellent substitute for a vacuum tube voltmeter in most instances when one is not available.

In this chapter, we will describe various voltage measurements which can be made with an oscilloscope. The advantages and disadvantages of using a scope will be discussed for each case. The applications described will undoubtedly suggest many others which may answer each serviceman's own specific problems of voltage measurement.

4.2 VOLTAGE MEASUREMENT PRINCIPLE

In Figure 1-7, the various viewing screen patterns shown from A to F indicate how the spot is deflected away from its at-rest center position to various locations on the screen by applying dc voltages to the deflecting plates. The patterns shown from G to J in the same figure show the straight-line traces obtained when the spot swings rapidly back and forth under the influence of alternating voltages applied to the deflecting plates.

These patterns are obtained with the linear sweep oscillator switched off, although the pattern shown in Figure 1-7(H) might be that of the sweep voltage alone when no signal voltage is present at the vertical deflecting plates.

Since the distance through which the spot moves, and the length of the trace both are proportional to the peak applied voltage, and since this distance and length can be measured easily on the viewing screen, it is plain that the screen may be calibrated as a voltmeter scale.

4.3 DC VOLTAGE MEASUREMENT

DC voltages can be measured with an oscilloscope with complete success only when they are applied *directly* to the deflecting plates and not through intervening series or parallel connected circuit components. Furthermore on both the Sylvania Oscilloscopes Types 131 and 132 dc voltages may not be measured through either the horizontal or vertical amplifier. DC voltage leads *can* be connected directly (not through amplifiers or capacitors) to the deflecting plates of the Sylvania Seven-Inch Oscilloscope Type 132 through the vertical deflection plate jacks on the rear of the instrument. On the three-inch scope Type 131, however, direct connection to deflecting plates is not possible without alterations in the oscilloscope circuit, which are not advisable. Because of their fluctuating nature, on the other hand, pulsating dc voltages usually may be measured easily through the vertical signal channel of either Sylvania Oscilloscope (with or without the amplifier, as the case may require) without making any changes in the instrument circuit.

This Section 4.3 dealing with oscilloscope measurements of dc voltages, therefore, will be valuable to an owner of the Sylvania Seven-Inch Oscilloscope Type 132. For others, although Section 4.3 will provide

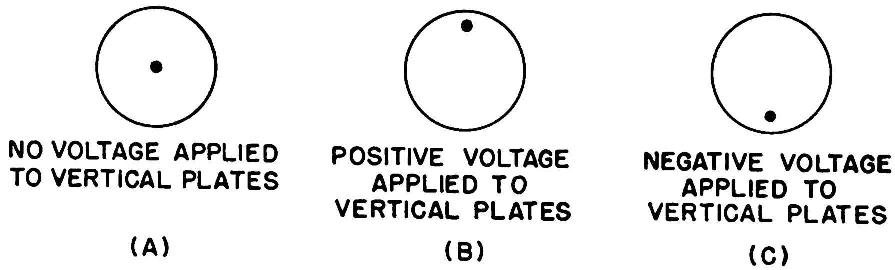


FIGURE 4-1 EFFECT OF DC VOLTAGE ON SPOT

interesting background for the discussion to follow on alternating voltage measurements, it will generally be advisable to employ a good voltmeter instead of an oscilloscope for pure dc measurements—preferably an electronic voltmeter with an extremely high input resistance, such as the Sylvania Polymeter.

A voltage of unknown value may be supplied to either the horizontal or vertical deflecting plates. But since the horizontal plates usually will be reserved for the time-base sweep voltage, most of our discussion will be confined to voltage measurements by means of the vertical plates.

When no voltage at all is applied to either set of plates, the spot occupies the center of the viewing screen, as shown in Figure 4-1(A), or it may be placed there by adjustment of the beam centering controls. This central position therefore may be regarded as the voltmeter zero. If the positive terminal of a dc voltage source is connected to the upper vertical deflecting plate (*directly*, not through a coupling capacitor), and the negative terminal of the common terminal of the cathode ray tube (or to the other vertical plate if a common terminal is not available), the spot will be deflected upward, as shown in Figure 4-1(B). The distance through which the spot moves away from its at-rest central position is proportional to the dc voltage. The linear sweep is not used here. A sufficiently large dc voltage will move the spot off the screen entirely, while a very small voltage will shift the spot vertically only a fraction of an inch. If a negative voltage is applied to the same vertical deflecting plate, the spot will be shifted downward, as indicated in Figure 4-1(C) a distance from center proportional to the applied negative voltage.

If a series of accurately-known positive and negative dc voltages are applied successively to the vertical plates and the corresponding spot displacements measured on the viewing screen and recorded, the screen then will be calibrated for dc voltages. Since response of the cathode ray tube is linear, however, not more than one accurate voltage check point ordinarily need be established. All voltages up to this point then may be identified as fractions of the calibration voltage. For example: if we find that 15 volts positive will shift the spot upward exactly one inch from the center of the screen, then a shift of half-inch indicates 7.5 volts, 2/3 inch shows 10 volts, etc., etc. Another way is to calibrate the graduated overlay disc of the viewing screen in terms of disc divisions. If we find, for example, that the spot moves 10 divisions upward from the center line of this disc upon application of 15 volts to the vertical plates, then our disc will indicate 1.5 volts per division. A

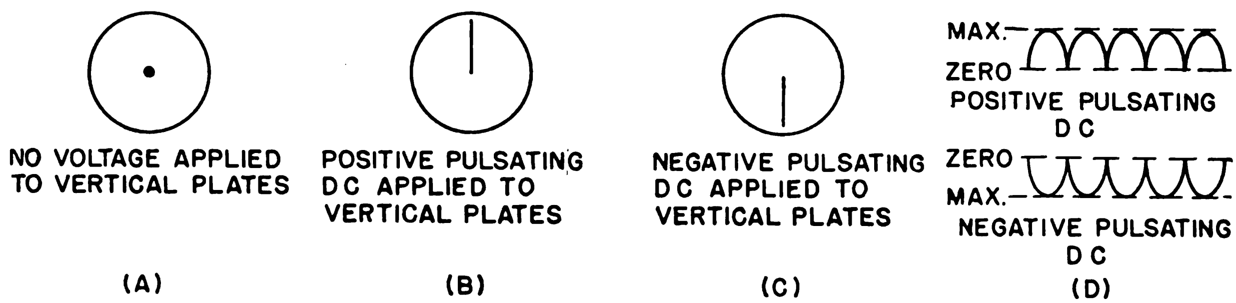


FIGURE 4-2 EFFECT OF PULSATING DC VOLTAGE ON SPOT

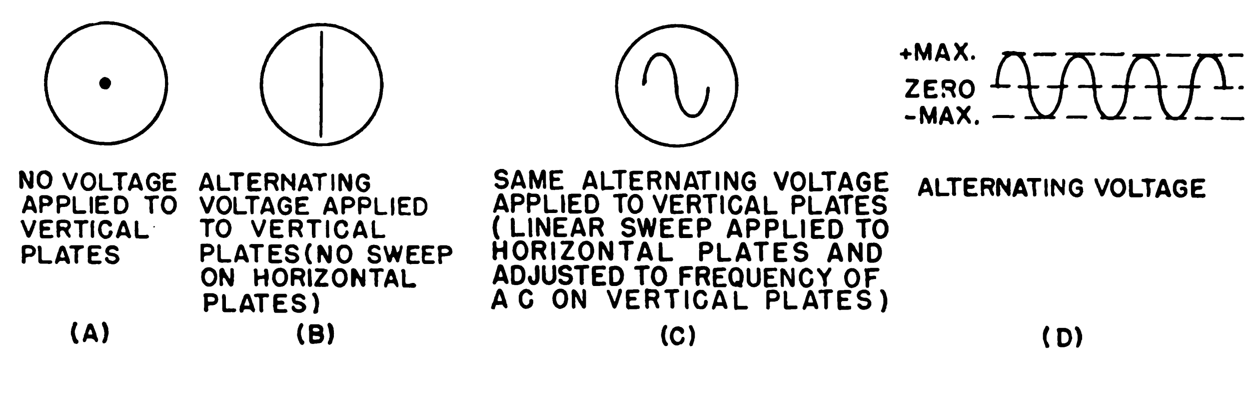


FIGURE 4-3 EFFECT OF ALTERNATING VOLTAGE ON SPOT

deflection of six divisions accordingly will show 9 volts, two divisions 3 volts, etc., etc.

The patterns shown in Figure 4-1 are obtained only with pure dc produced by a battery or an excellently-filtered power supply. If any ripple is present a pulsating positive or negative voltage results. The waveforms of pulsating dc voltages are shown in Figure 4-2(D). These voltages cause the spot to move back and forth, to and from the center zero position, tracing out a line. A pulsating positive voltage produces a line extending upward from center, as shown in Figure 4-2(B); while a negative pulsating voltage establishes a vertical line extending downward from center, as shown in Figure 4-2(C). The length of the trace is proportional in each case to the peak value of the pulsation (positive or negative half-cycle), and the scale of the viewing screen may be calibrated to read this voltage in the same manner just described for pure dc voltages. The length of the entire trace corresponds to the peak value of the voltage pulsation, while 70.7% of this length corresponds to the effective or rms value.

4.4 ALTERNATING VOLTAGE MEASUREMENTS

When an alternating voltage (see Figure 4-3(D) is applied to the vertical deflecting plates; the spot is shifted vertically up and down from the center of the screen by the positive and negative half-cycles, respectively. When no sweep voltage is applied to the horizontal deflecting plates; this rapid movement of the spot traces out a vertical line, as shown in Figure 4-3(B), which extends both above and below the center line. The height of the upper half of the line, measured from the center to the top, indicates the peak value of the positive half-cycle of the applied alternating voltage. The depth of the lower half of the trace, measured from center to the lower tip, indicates the peak value of the negative half-cycle of the applied voltage.

When the same value of alternating voltage is applied to the vertical plates and a linear sweep voltage is applied to the horizontal deflecting plates, the pattern on the screen takes the shape of a single cycle of the applied voltage when the sweep frequency is

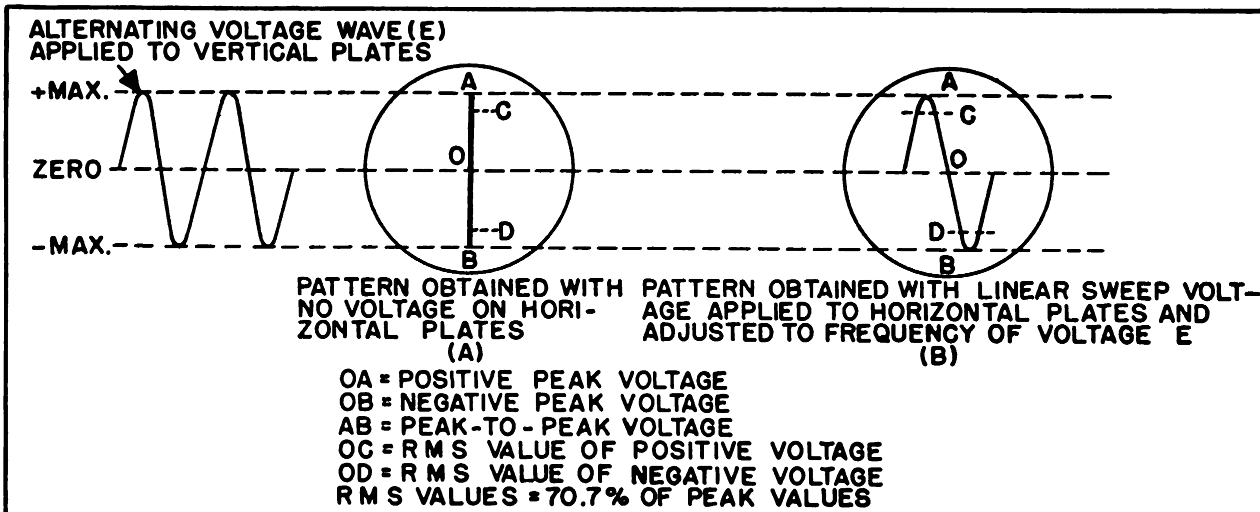


FIGURE 4-4 VOLTAGE RELATION IN SYMMETRICAL ALTERNATING VOLTAGE PATTERNS

adjusted to that of the applied voltage. This pattern is shown in Figure 4-3(C). Unlike the simple trace shown in Figure 4-3(B), the waveform, shown in Figure 4-3(C), shows not only positive and negative peak voltage values, but the waveform as well. Additional information gained from a study of the latter pattern includes, (1) whether the positive and negative peaks are of the same amplitude (that is, whether the wave is symmetrical), (2) whether the voltage is a true sine wave or is distorted, and (3) whether the voltage under study has constant frequency.

Voltage relations in the straight-line and sine-wave traces are illustrated by Figure 4-4. At (A) in this Figure, we have the simple trace resulting when sine-wave alternating voltage E is applied to the vertical deflecting plates and no voltage is applied to the horizontal plates. At (B) is shown the single sine-wave cycle resulting when, in addition, a linear sweep voltage of the same frequency is applied to the horizontal plates.

In each pattern the height measured center of screen to the upper tip of the image indicates the peak voltage of the positive half-cycle. This is the distance OA. Similarly, OB (the distance measured down from center to the lower tip of the pattern) indicates the peak voltage of the negative half-cycle. Distance OC is 70.7% of the upper half and therefore indicates the effective or rms voltage of the positive half-cycle, while distance OD is 70.7% of the lower half and indicates the rms voltage of the negative half-cycle. Distance AB, measured from one tip of the pattern to the other, indicates the peak-to-peak voltage. A point 63.6% above or below center would indicate the average value of a sine wave voltage half-cycle.

The oscilloscope patterns shown in Figure 4-4 assume a symmetrical applied voltage; that is, one having equal positive and negative half-cycles. Very often, the voltages encountered in electronic testing are not symmetrical. Figure 4-5 shows an example of this condition. Here the positive half-cycles are noticeably taller than the negative half-cycles. Although the positive peak and rms values in Figure 4-5 and the peak-to-peak values as well are the same as in Figure 4-4, the negative peak and negative rms values are less than in Figure 4-4(A). One of the advantages of the oscilloscope as an ac voltmeter is this ability to show readily the waveform of the voltage under study. In many electronic tests, it is important to have such information.

4.5 SENSITIVITY OF OSCILLOSCOPE VOLTMETER

Because the vertical amplifier serves to increase the signal voltage before it is presented to the vertical deflecting plates, good sensitivity is obtained with the complete oscilloscope employed as an ac voltmeter.

In Section 3.2, we pointed out that 0.5 volt rms will produce a 1-inch peak-to-peak deflection on the screen of the Sylvania Three-Inch Oscilloscope Type 131 when the vertical amplifier is used. But when the amplifier is not used, 17 volts rms are required for the same deflection. This means that the amplifier increases the sensitivity of the 3AP1 cathode ray tube, as an ac voltmeter, 34 times.

Similarly, 0.21 volt rms will produce a one-inch peak-to-peak deflection on the screen of the Sylvania Seven-Inch Oscilloscope Type 132 when the vertical amplifier is used (see Section 3.3), but 15 volts rms are required for the same deflection when the amplifier is not used. This indicates that the sensitivity of the 7GP1 cathode ray tube, as an ac voltmeter, is increased 71½ times by the vertical amplifier in this instrument.

The vertical amplifier thus makes possible oscilloscope measurement of small voltages, within the frequency range of the instrument, which might not be detectable with an available ac voltmeter. For still greater sensitivity, an external amplifier of known gain may be used ahead of the vertical amplifier in the oscilloscope.

It can be seen that it is important when warming up the oscilloscope to center the dot which represents the electron beam (while the sync selector switch is turned to "external") exactly in the center of the viewing screen. If this is done, whether a voltage waveform is symmetrical or not can be determined easily by noticing whether the peak values of the positive and negative half cycles lie an equal number of screen divisions above and below the center line of the screen.

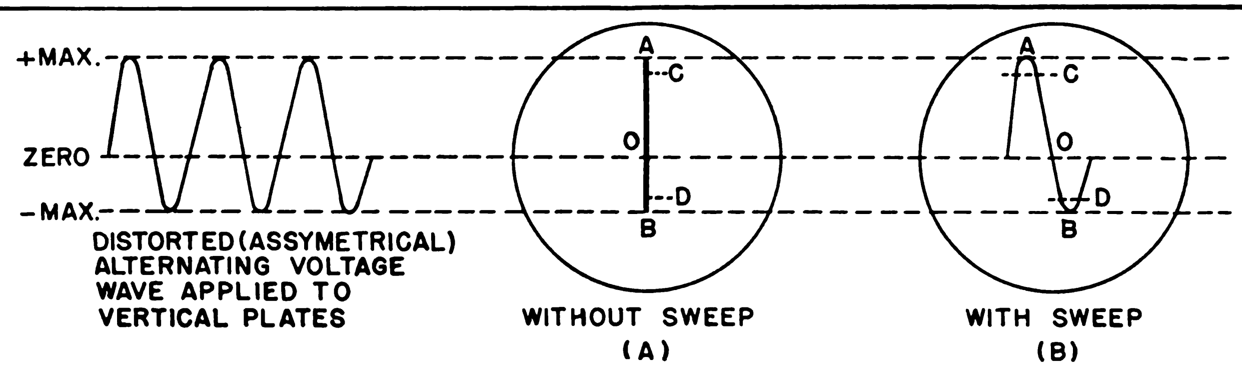


FIGURE 4-5 VOLTAGE RELATIONS IN DISTORTED ALTERNATING VOLTAGE PATTERNS

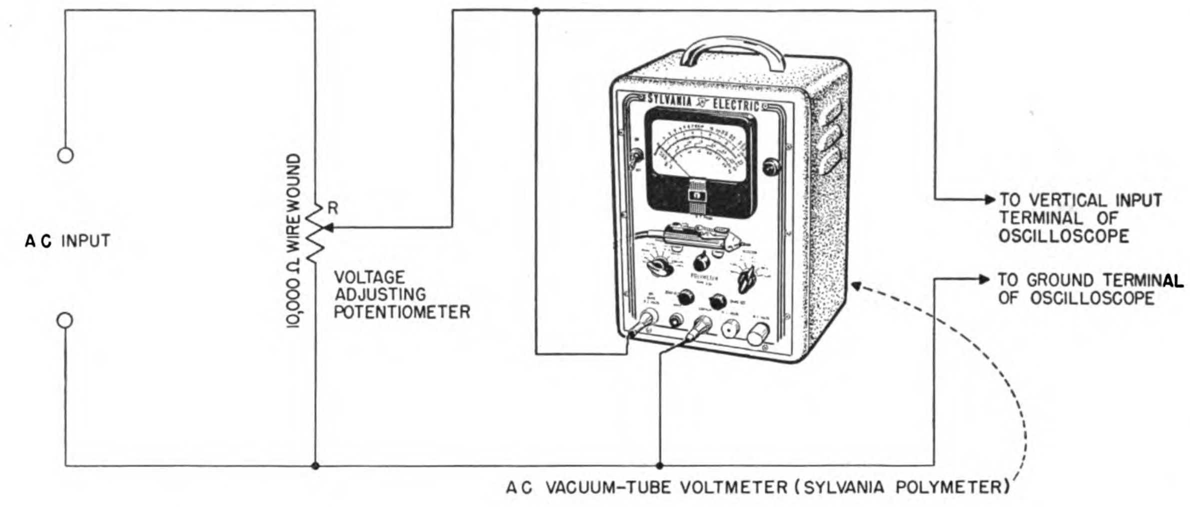


FIGURE 4-6 CIRCUIT FOR VOLTAGE CALIBRATION OF OSCILLOSCOPE

Sensitivity of the oscilloscope is reduced when the vertical gain control is turned down. However, this very feature enables the gain control to act as an input voltage divider (voltmeter multiplier), permitting higher voltages to be applied to the oscilloscope vertical input terminals. Calibration of the gain control will be discussed in Section 4.7.

4.6 CALIBRATION OF OSCILLOSCOPE AS VOLTMETER

Figure 4-6 shows a circuit arrangement for calibrating the vertical deflection of the oscilloscope in terms of voltage. Apply an alternating voltage to the two input terminals of the circuit. Select various fractions of this input voltage for the vertical input terminals of the oscilloscope by means of the potentiometer, R. The selected voltage values are indicated continuously by an ac vacuum tube voltmeter, such as the Sylvania Polymeter. The input voltage may be supplied by a sine-wave audio oscillator, such as the Sylvania Audio Oscillator Type 145, set to any frequency between 50 and 10,000 cycles, or by the 6.3-volt secondary winding of a transformer operated from the power line. An alternative circuit in which a Variac is used instead of a potentiometer is shown in Figure 4-7.

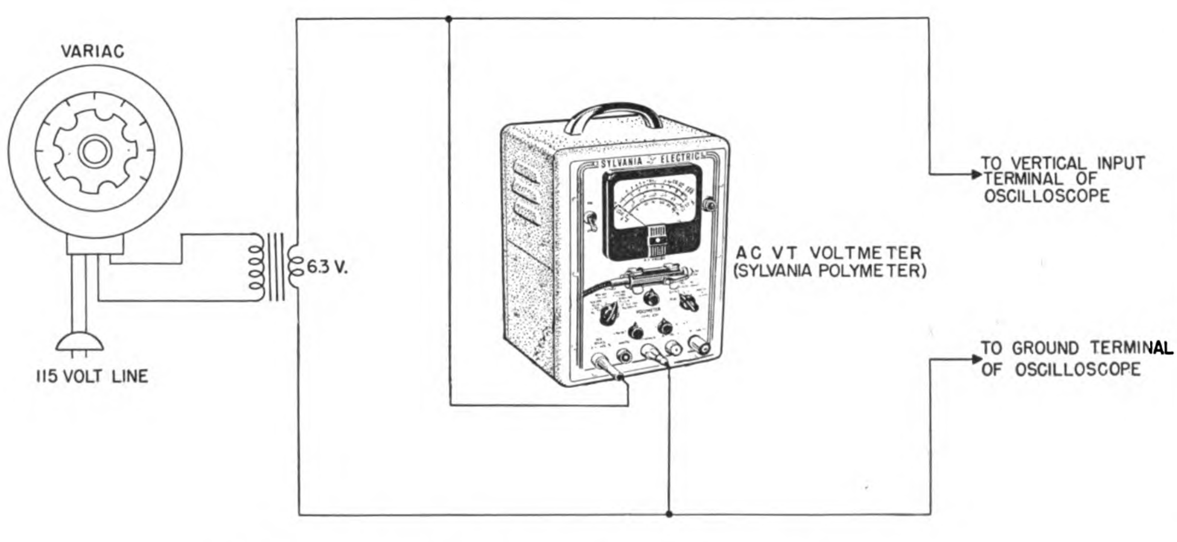


FIGURE 4-7 ALTERNATIVE CIRCUIT FOR VOLTAGE CALIBRATION

The following test procedure is recommended for the calibration:

(1) Place oscilloscope into operation: (a) Set vertical gain control to maximum, (b) switch-off sweep oscillator, (c) set sync selector switch to EXTERNAL, (d) set spot evenly on a horizontal line at or near center of screen, (e) focus spot carefully, and (f) use minimum intensity for accurate visibility.

(2) Connect calibration circuit according to Figure 4-6 or 4-7. Set potentiometer or Variac to zero.

(3) Set ac vacuum tube voltmeter to 0—3-volt scale.

(4) Slowly advance potentiometer or Variac, noting that vertical trace on screen begins extending up and down from zero horizontal line. Trace is identical with that shown in Figure 4-3(B) and in Figure 4-4(A). Set potentiometer or Variac to bring upper tip of trace exactly to first horizontal line above zero line (an increase of 1 division). Descent of trace below zero line will be 1 division if wave is symmetrical. (See Figure 4-4).

(5) At this point, take voltage reading from ac vacuum tube voltmeter. This is the rms voltage per screen division.

(6) Advance potentiometer or Variac to bring upper tip of trace to second horizontal line above zero line, noting that voltmeter reading now is twice value obtained in (5).

(7) Take similar voltage readings at each successive horizontal line on viewing screen, if desired. This seldom will be necessary, however, since several such measurements will show response of instrument to be linear.

(8) If peak voltage values are desired, multiply voltmeter readings obtained by 1.41.

Note that the data taken in this procedure correspond to maximum setting of the vertical gain control. The volts per division will increase progressively as the gain control setting is decreased. Calibration of this control will be explained next.

4.7 GAIN CONTROL CALIBRATION

The vertical gain control can function as an input voltage divider (voltmeter multiplier). In the complete oscilloscope, such as Sylvania Types 131 and 132, this control is provided with a numerical scale which may be calibrated easily by the following procedure:

(1) Set up apparatus as instructed in Section 4.6.

(2) With vertical gain control at maximum (10 on dial), determine voltage input required for deflection of one vertical division on oscilloscope screen.

(3) Reduce gain control setting to next lower scale division (9) and readjust ac input voltage, by means of potentiometer or Variac, to re-establish one division deflection on screen. Observe meter reading.

(4) Repeat Steps 2 and 3 at other settings of gain control, recording volts-per-division values for each setting.

Below is a sample table showing the vertical gain control calibration made for one Sylvania Three-Inch Oscilloscope Type 131:

VERTICAL GAIN CONTROL SCALE SETTING	rms VOLTS PER SCREEN DIVISION
10	0.06
8	0.07
6	0.10
4	0.16
2	0.40

4.8 CALIBRATION OF DIRECT INPUT

To calibrate the oscilloscope as an ac voltmeter for the direct application of unknown voltages to the vertical deflection plates without vertical amplification, follow the procedure outlined in Section 4.6, except switch-off the vertical amplifier and allow the test voltage to go directly to the vertical plates. A higher test voltage source must be used in this calibration since sensitivity of the cathode ray tube will be lower (volts per division will be higher) when no amplification is present.

4.9 VOLTAGE CALIBRATION OF HORIZONTAL PLATES

Some servicemen prefer a horizontal trace for oscilloscope voltage indications. This is entirely permissible if the linear sweep is not to be used. Straight-line voltage traces, for example, do not require the sweep.

To calibrate the horizontal trace, follow the procedures outlined in Sections 4.6, 4.7, and 4.8, except apply the variable input voltage to the horizontal input terminals of the oscilloscope and reduce the setting of the vertical gain control to zero to prevent extraneous signal pickup.

4.10 EXTENSION OF SCREEN SCALE

A sufficiently high test voltage will deflect the trace beyond the top and bottom of the viewing screen when zero is taken as the center of the screen. If reducing the gain control setting does not take care of the situation, this condition may be overcome by setting the spot initially near the bottom of the screen for separately observing the positive half-cycle voltage, and near the top of the screen for observing the negative half-cycle.

When the horizontal trace is used for voltage readings and the trace is carried off the sides of the screen, the spot should be set initially near the left-hand end of the screen for separately observing the positive half-cycle voltage, and near the right-hand side of the screen for observing the negative half-cycle voltage.

CHAPTER V

USE OF THE OSCILLOSCOPE IN RADIO RECEIVER SERVICING

5.1 AM RECEIVER ALIGNMENT, USING AM SIGNAL GENERATOR

In the radio receiver service shop, the oscilloscope is a precise, time-saving instrument in such dynamic tests (tests made while the circuit is in operation) as set alignment, checking set performance, tracing signals, locating faulty tubes, capacitors, and resistors; tracking down hum, regeneration, oscillation, and noise; discovering and identifying overloading and distortion; and in general trouble-shooting. The various receiver test operations are described, step by step, in this chapter.

When an amplitude-modulated signal generator is used in the stage-by-stage alignment of a radio receiver, the oscilloscope acts as an alignment peak indicator. In this application the vertical input terminals of the oscilloscope are connected across the loudspeaker voice coil as shown in Figure 5-1. Ac-

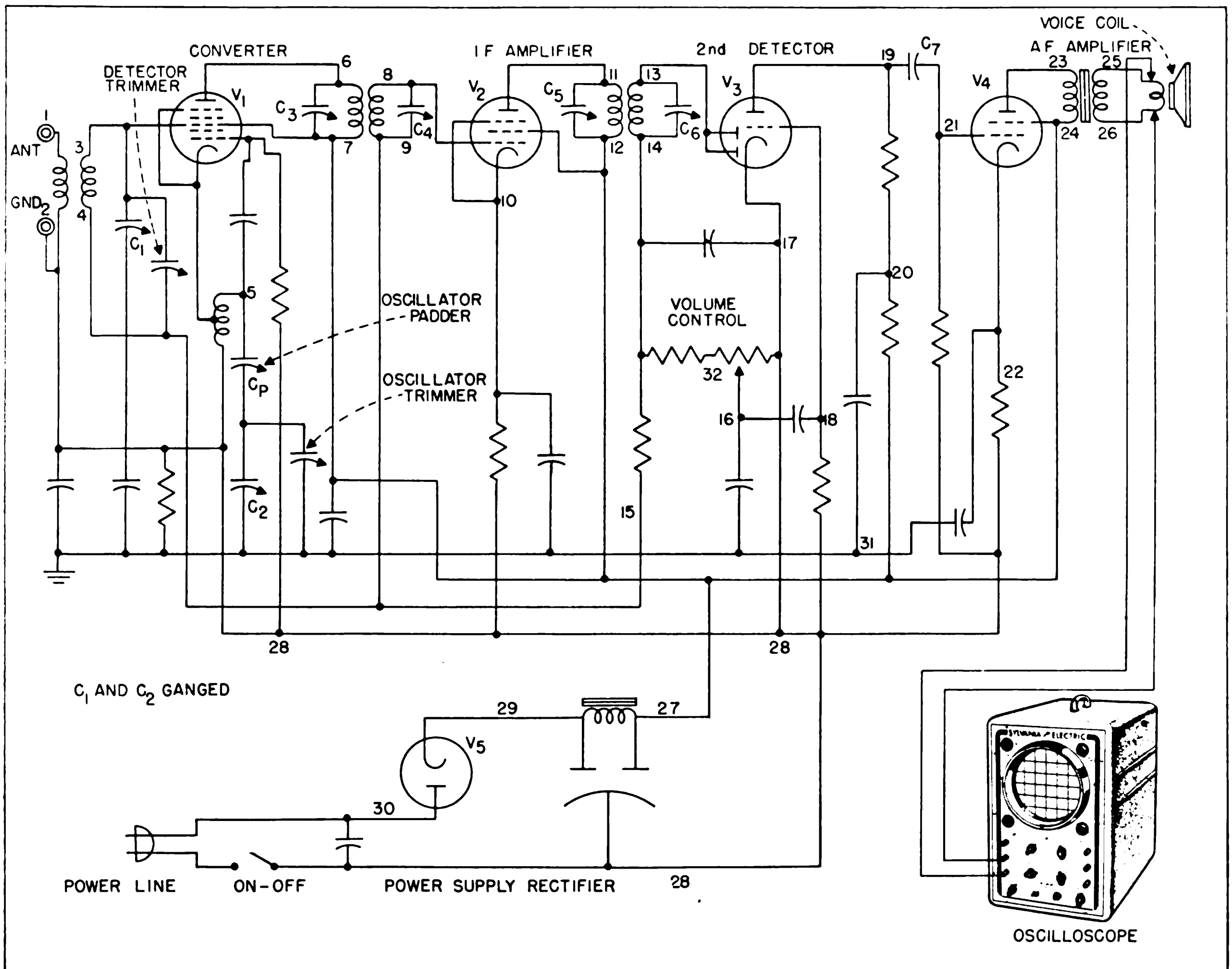


FIGURE 5-1 AC-DC SUPERHETERODYNE RECEIVER ARRANGED FOR OSCILLOSCOPIC ALIGNMENT

curate alignment may be obtained with this arrangement.

The following steps give the procedure to be followed in aligning an AM superheterodyne receiver. The circuit given in Figure 5-1 is typical of most sets.

(1) Interrupt avc in receiver by connecting temporary wire jumper between points 15 and 28. Remove jumper as soon as alignment is completed. Insert receiver plug into power line. Set volume control at about ½ maximum. Tune receiver dial until variable condenser plates are completely meshed.

(2) Adjust AM signal generator to intermediate frequency of receiver, usually 455 kc, switch-on 400 cycle modulation, set attenuators at zero, and insert signal generator plug into power line.

(3) Prepare oscilloscope: *For vertical straight-line pattern*, switch-off linear sweep, set SYNC switch to EXTERNAL, set FREQUENCY controls to zero, set GAIN controls to zero, set INTENSITY and FOCUS controls for sharp dot on screen. *For sine-wave pattern;* set linear sweep to any frequency near 100 cycles, set VERTICAL GAIN control to zero, set SWEEP AMPLITUDE control to maximum, set SYNC switch to INTERNAL, adjust HORIZONTAL GAIN control, FOCUS and INTENSITY controls for long, clear horizontal line on screen. Either the straight line or sine wave pattern will be satisfactory, and the operator should make his own choice between the two.

(4) Connect VERTICAL INPUT terminals of oscilloscope to voice coil of loudspeaker, as shown in Figure 5-1.

(5) Connect ground terminal of signal generator to point 31. Provide "high" terminal of signal generator with short, shielded test lead with blocking capacitor of 0.05 or 0.1 μf.

(6) To test af amplifier of receiver, connect lead from 400-cycle output terminal of signal generator to 21. Slowly advance vertical gain control of oscilloscope, noting that height of pattern increases, until pattern is about 1½ inch high. If no pattern is obtained, af amplifier is not operating. Removing 400-cycle signal from 21 should cause pattern to return to dot or line. Make additional af test with 400-cycle lead at 18.

(7) Remove 400-cycle signal and connect high terminal of signal generator (set to receiver intermediate frequency) to 8. Increase setting of attentuators in signal generator, and adjust trimmers C_5 and C_6 for peak height of pattern on screen. If pattern is not large enough, advance settings of attenuators and vertical gain control.

(8) Transfer high lead of generator to 3, and adjust trimmers C_3 and C_4 for peak height of pattern If pattern extends off screen, reduce setting of receiver volume control, oscilloscope vertical gain control, signal generator attenuators, or all three.

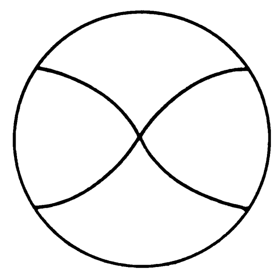


FIGURE 5-2 PATTERN INDICATING SWEEP OSCILLATOR ADJUSTED TO 120~

(9) Transfer high lead of generator to 1, set signal generator to 1500 kc, set receiver dial to 1500 kc, and adjust trimmers on detector tuning capacitor to C_1 and oscillator tuning section C_2 for peak height of pattern. Reduce attenuator setting if pattern is too high.

(10) With same connections as in (9), set generator and receiver to 600 kc and adjust padder cp on oscillator section of tuning capacitor for peak height of pattern.

(11) After readjusting *all* detector and if trimmers, remove jumper from points 15 and 28.

5.2 AM RECEIVER ALIGNMENT, USING FM SIGNAL GENERATOR

The method which will be described in this section has the advantage that the oscilloscope pattern it yields is the actual selectivity curve of the rf detector, or if stage under test—or of the entire receiver. Observation of this curve shows quickly whether the circuit is sharply or broadly tuned. This method of alignment requires, in addition to an oscilloscope, a frequency-modulated signal generator, such as the Sylvania Type 216.

(1) Prepare oscilloscope according to instructions given for *sine-wave pattern* in Step 3 in Section 5.1, except set linear sweep to 120 cycles in following manner: (a) Connect 60-cycle voltage to vertical amplifier input terminals and advance vertical gain control to about ¼ maximum. 60-cycle voltage may be obtained from the 6.3-volt output terminal of Sylvania Oscilloscopes Types 131 and 132. (b) Set sync switch to LINE FREQ. (c) Adjust coarse and fine frequency controls and sync amplitude control to obtain *stationary* pattern shown in Figure 5-2, indicating sweep oscillator is set to 120 cycles. (d) Without disturbing control settings, remove 60-cycle voltage from vertical input terminals. (e) Throw sync switch to EXTERNAL.

(2) Plug-in frequency-modulated signal generator and set dial to receiver intermediate frequency.

(3) Interrupt avc in receiver by connecting temporary jumper from 15 to 28 (see Figure 5-1). Re-

move jumper as soon as alignment is completed. If receiver is not ac-dc, connect jumper instead from 15 to chassis ground.

(4) Plug-in receiver and detune receiver dial away from any strong local carriers.

(5) Connect vertical input terminals of oscilloscope to 31 and 32 (grounded terminal of oscilloscope to 31). Advance vertical gain control slightly. Do not disturb sweep oscillator or sync settings.

(6) Connect sync output terminal of signal generator to sync input terminal of oscilloscope.

(7) Connect low terminal of generator to 31; high terminal to 8. Use short, shielded lead for latter connection. Advance attenuators and set FM sweep width control in generator to 10 kc.

(8) Adjust if trimmers C_5 and C_6. Transfer high lead to 3, and adjust trimmers C_3 and C_4. One of the patterns shown in Figure 5-3 will be seen on the screen. If pattern drifts across screen, adjust sync amplitude control to "freeze" image. Figure 5-3(A) indicates good alignment and good circuit operation. Note that this selectivity curve is neither too sharp nor too broad. Overloading is indicated by Figure 5-3(B) and 5-3(C). Figure 5-3(D) is the flat-topped curve which usually results from "staggering"—that is, setting the various trimmers to opposite sides of resonance. The double curve, Figure 5-3(E), indicates very bad misalignment, and usually is the pattern first seen before the trimmers are adjusted.

(9) Transfer generator high lead to 1, set signal generator and receiver dials to 1500 kc, and adjust trimmers on detector and oscillator sections on tuning capacitor C_1-C_2 for sharp pattern of type shown in Figure 5-3(A).

(10) Set signal generator and receiver dials to 600 kc, and repeat Step 9, but adjusting oscillator padder cp instead of trimmers.

(11) After readjusting all detector and if trimmers, remove jumper from 15 and 28.

5.3 ALIGNING FLAT-TOPPED HIGH-FIDELITY RECEIVERS

Visual alignment of high-fidelity tuned rf or superheterodyne receivers which employ broadly-tuned stages is performed in the same manner outlined in Section 5.2, except that the desired alignment pattern resembles Figure 5-3(D). The width of the pattern (selectivity curve) in kilocycles may be determined by referring to the scale of the sweep width control on the FM signal generator used. Section 5.8 describes a method of measuring curve width when the generator has no calibrated sweep width control. The width, however measured, must correspond to that recommended by the set manufacturer.

The purpose of flat-top alignment, necessary to insure a high-fidelity pass band, is to obtain a curve (pattern) with a top as straight and horizontal as possible. The flat top must be obtained without too much loss of height or top tilting, such as illustrated by the pattern in Figure 5-3 (F).

In alignment of the high-fidelity receiver, the vertical input terminals of the oscilloscope are connected to the diode load resistor, as explained in Section 5.2. However, when the receiver employs a power detector instead of the diode type (as almost always is the case when a tuned rf circuit is used), the high vertical input terminal of the oscilloscope must be connected to the plate end of the detector plate load resistor. The ground terminal of the oscilloscope is connected to chassis ground of the receiver, or to B-minus when the chassis is not at ground potential.

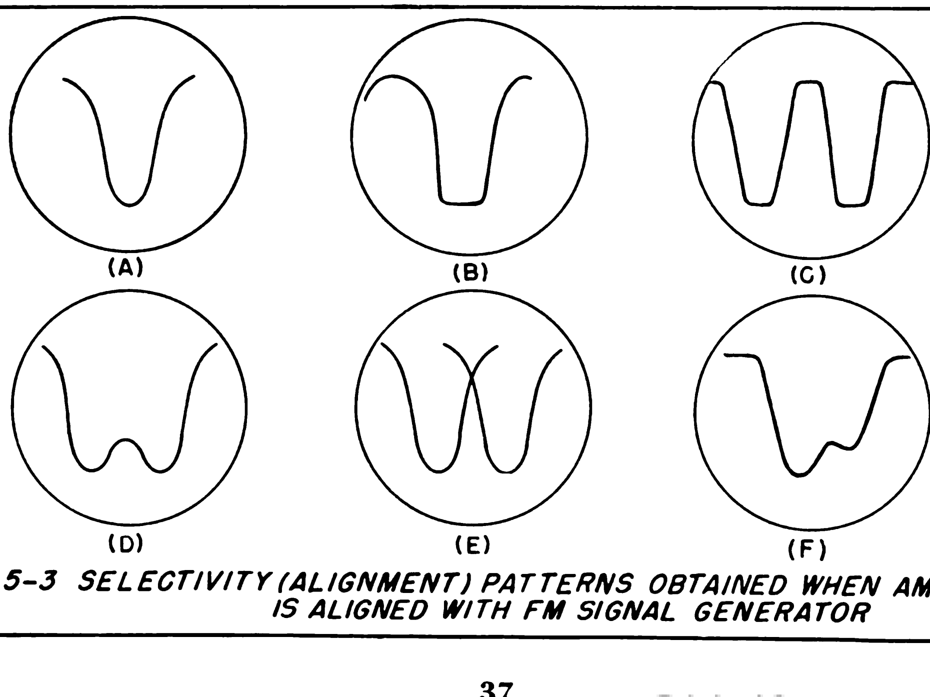


FIGURE 5-3 SELECTIVITY (ALIGNMENT) PATTERNS OBTAINED WHEN AM RECEIVER IS ALIGNED WITH FM SIGNAL GENERATOR

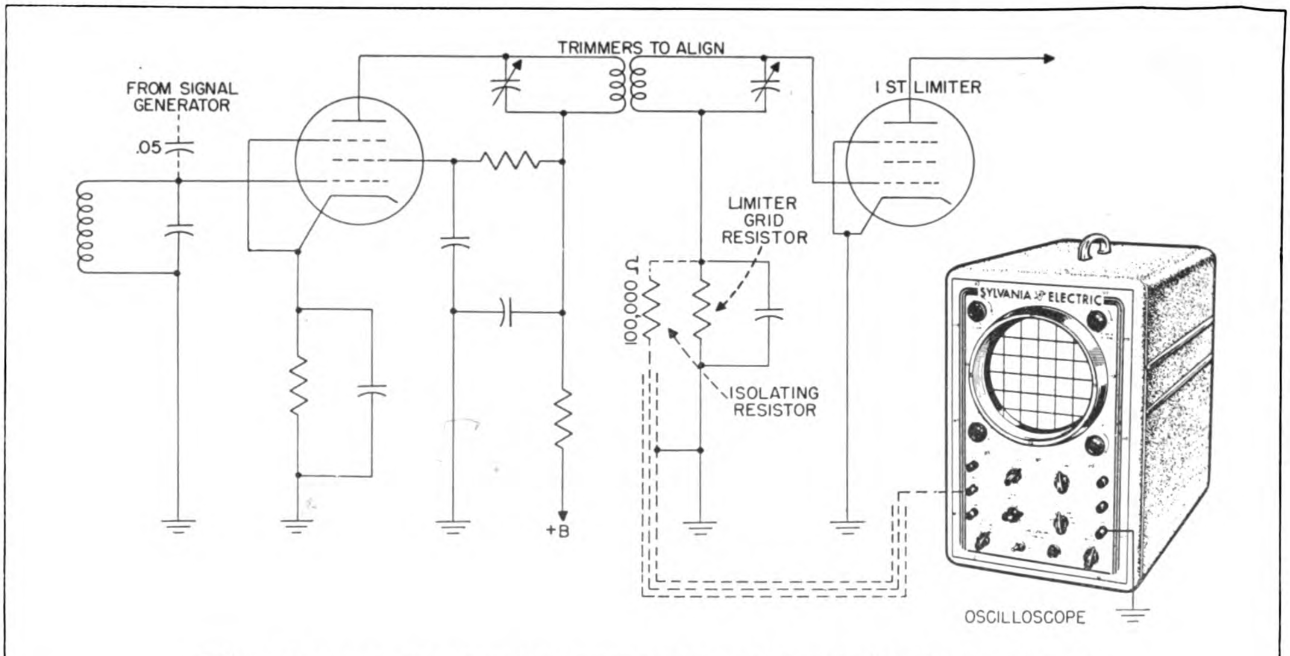


FIGURE 5-4 OSCILLOSCOPE CONNECTIONS FOR IF ALIGNMENT IN FM RECEIVER

5.4 ADDITIONAL INSTRUCTIONS ON RECEIVER ALIGNMENT

Many receivers do not employ capacitive trimming and tuning of the type shown in Figure 5-1. These sets usually make use of powdered-iron slugs for inductive tuning and trimming. Visual alignment of such receivers is done in the same way as outlined in the foregoing sections, except that slugs instead of capacitors must be adjusted in the rf, detector, if and oscillator stages. No special connections, not already covered in the text, need be made.

In an all-wave receiver, alignment of the front end of set must be completed for each setting of the band switch. The generator must be set successively to frequencies near the top and bottom of each wave band, just as the frequencies of 1500 and 600 kc were used for alignment of the broadcast range. Alignment of if and 2nd detector stages need be performed only once.

The circuit shown in Figure 5-1 is an ac-dc set powered by a simple line rectifier. The avc is interrupted in this circuit (see Sections 5.1 and 5.2) by connecting a short-circuiting jumper temporarily from point 15 to B-minus (point 28). In straight ac receivers, the jumper must be run from point 15 to chassis ground.

Occasionally, connection of an oscilloscope to a radio receiver results in pickup of outside signals, noise, or hum voltage, or in internal regeneration or oscillation. Either of these conditions will cause modulation or distortion of the pattern on the screen. Usually, a short, well-shielded lead to the vertical input terminals will correct the trouble. In stubborn cases, it may be necessary to include a 50,000- to 100,000-ohm series resistor in the vertical input lead as close as practicable to the point of contact in the receiver circuit.

5.5 FM RECEIVER ALIGNMENT

From the antenna and ground input terminals through the if amplifier, the FM receiver is similar to, and often identical with an AM superheterodyne. The audio stages of the FM receiver likewise are identical with those in an AM set. The point of difference is that the AM receiver utilizes a second detector between the if and af amplifiers, while the FM receiver uses a discriminator (preceded by one or more limiter stages) in this same position. More recently-designed FM receivers employ a special type of discriminator, the *ratio detector,* which requires no limiter section.

Alignment of the FM receiver differs from AM alignment chiefly in the special adjustment of the discriminator or ratio detector. However, to make the operation clear we will explain separately in the following paragraphs the adjustment of each of these circuits.

Discriminator-Type Receiver. (1) Prepare oscilloscope in same manner outlined in Step 1 of Section 5.2.

(2) Connect sync input terminals of oscilloscope to 120-cycle sync output terminal of frequency-modulated signal generator.

(3) Set generator output to intermediate frequency of receiver (usually 10.7 mc).

(4) Connect short, shielded "high" lead of generator to grid of last if stage.

(5) Via a short, shielded lead, connect vertical input terminal of oscilloscope to junction of limiter grid resistor and secondary of last if transformer, as shown in Figure 5-4.

(6) Adjust trimmers of last if stage to obtain a pattern similar to Figure 5-3(D). Bandwidth of an FM if amplifier is somewhat broader than that of an AM

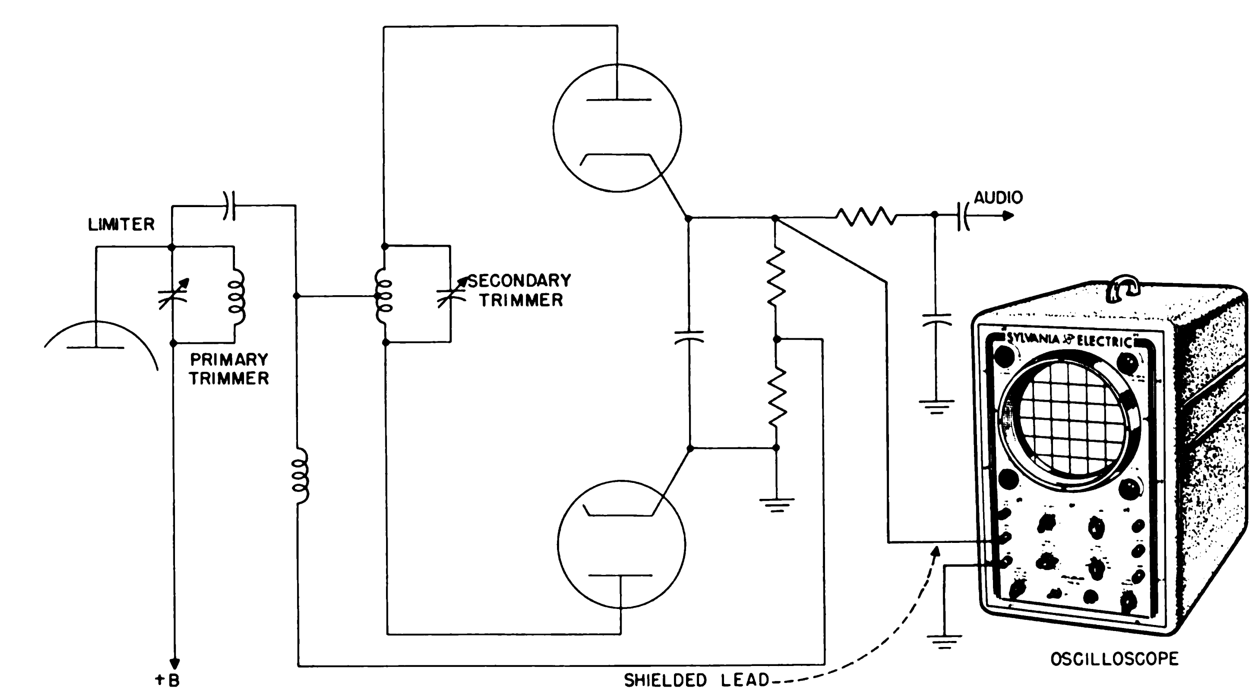


FIGURE 5-5 OSCILLOSCOPE CONNECTIONS FOR DISCRIMINATOR ALIGNMENT

if amplifier, consequently the sharp curve of Figure 5-3(A) must not be expected.

(7) Transfer generator output to detector grid of converter (mixer) stage (such as point 3 in Figure 5-1) and adjust remaining if trimmers for peak height of pattern on screen.

(8) Finally, "touch up" all if trimmers for close adjustment.

(9) For discriminator alignment, transfer vertical input of oscilloscope to top of discriminator load resistor string, as shown in Figure 5-5. Generator output must be connected to detector grid of converter stage. Pattern seen on screen will resemble Figure 5-8 when signal generator sweep frequency is same as line frequency and sync frequency is twice line frequency. Trimmers of discriminator transformer must be adjusted to bring points A and C, or E and G, equal distances from horizontal center line (B or F). Also, adjustment must be continued to bring B and F equal distances from D. Slant lines AG and CE will intersect, with point D resting on the horizontal line when alignment is correct. Adjustment of primary trimmer of discriminator transformer controls distance of points A, C, E, and G from horizontal center line; adjustment of secondary trimmer controls position of cross-over point D with respect to horizontal center line and spacing from points B and F.

(10) If oscilloscope is synchronized at line frequency, instead of twice that value, and signal generator sweep is same as line frequency, the dual pattern shown in Figure 5-9 will be seen on screen during discriminator alignment. Discriminator transformer trimmers must be adjusted, in this case, to bring points B and D (or B′ and D′) equal distances from horizontal center line, and points A and E equal distances from C—or A′ and E′ equal distances from C′.

Ratio Detector-Type Receiver. The if amplifier of an FM receiver employing a ratio detector must be aligned in the same manner as the if section of a discriminator-type set (see Section 6.5), except that the vertical input terminal of the oscilloscope must be connected to the top of the detector load resistor (point A in Figure 5-6) for alignment of the if amplifier up to and including the *primary* of the ratio detector transformer.

(1) To align secondary of ratio detector transformer, transfer vertical input terminal of oscilloscope to point B (see Figure 5-6) and adjust secondary trimmer. The pattern seen on oscilloscope screen will depend upon synchronizing frequency. Pattern shown in Figure 5-8 will be seen when signal generator sweep rate and sync frequency both are twice the line frequency. Pattern shown in Figure 5-9 will be seen when sweep rate is same as line frequency and sync frequency is twice that value.

(2) Adjust detector trimmers for symmetry of pattern, as instructed in Step 9, Section 5.5.

(3) Work back and forth with vertical input terminals of oscilloscope successively at points A and B

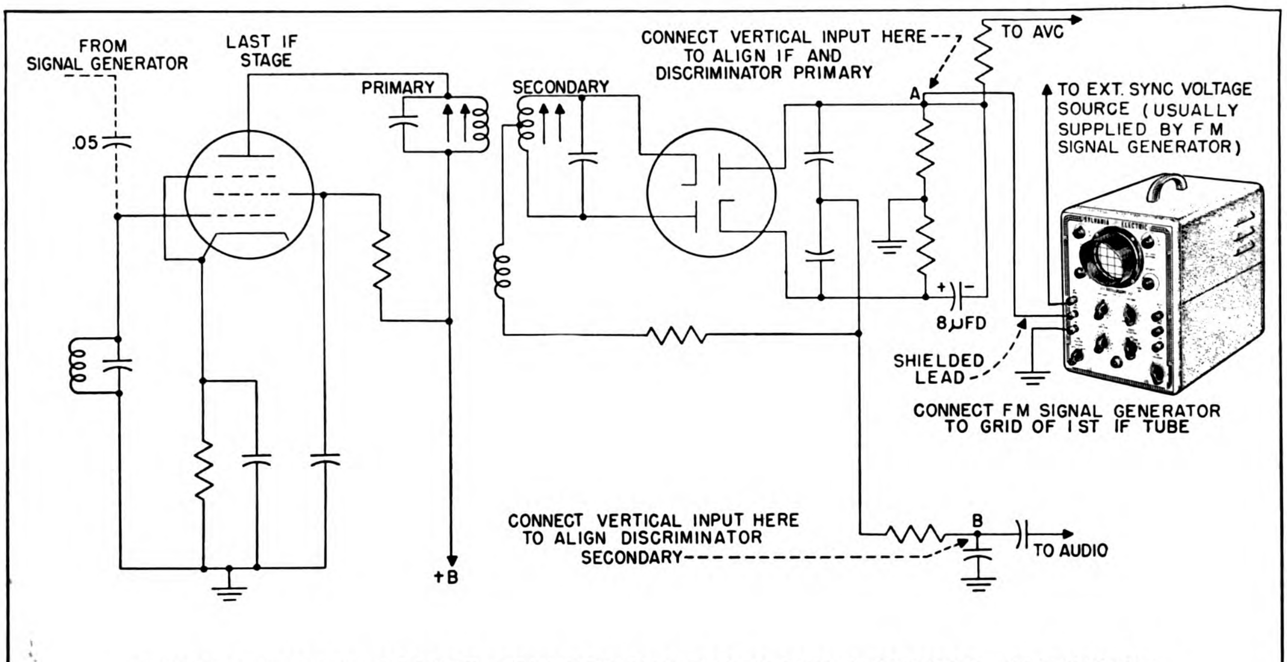


FIGURE 5-6 OSCILLOSCOPE CONNECTIONS FOR RATIO DETECTOR ALIGNMENT

(See Figure 5-6) for close alignment of both primary and secondary of ratio detector transformer.

(4) If load resistor of ratio detector does not have grounded center point, as shown in Figure 5-6, but one end grounded as in Figure 5-7, vertical input of oscilloscope must be connected to junction of two matched 250,000-ohm 1-watt carbon resistors. These connections are shown in Figure 5-7. After final adjustment of detector, these resistors must be removed from circuit.

Front End Alignment. The front end of an FM receiver (that is, the converter, mixer, or first detector-oscillator section) resembles that of any other superheterodyne, except that the input tuning will cover 88 to 108 megacycles, and in some cases 42-50 Mc (old FM band) as well. Alignment is the same as described for AM front ends (see Steps 9 and 10 in Section 5.2), except that the signal generator is set to 108 Mc for the high-end adjustment and to 88 Mc for low-end adjustment.

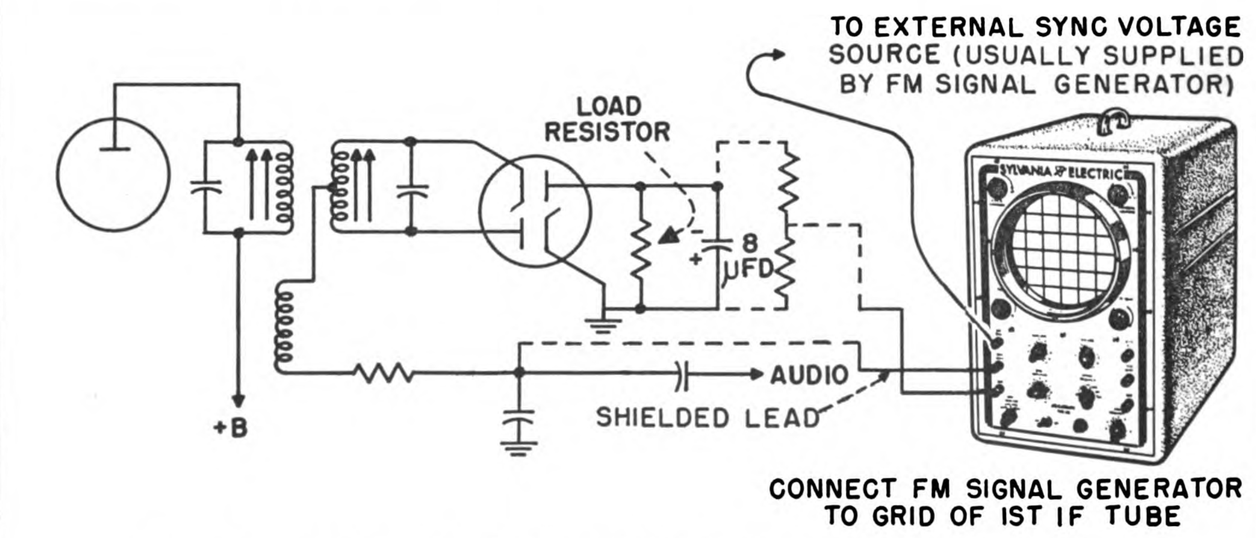


FIGURE 5-7 ALTERNATE OSCILLOSCOPE CONNECTIONS FOR RATIO DETECTOR ALIGNMENT

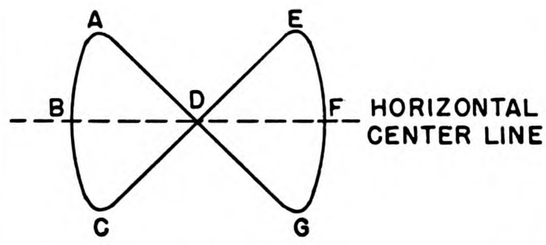


FIGURE 5-8 DISCRIMINATOR OR RATIO DETECTOR ALIGNMENT PATTERN. (SYNC VOLTAGE HAS TWICE POWER LINE FREQUENCY)

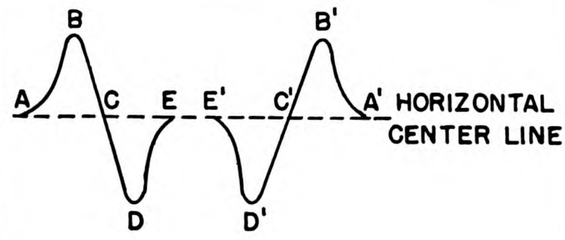


FIGURE 5-9 DISCRIMINATOR OR RATIO DETECTOR ALIGNMENT PATTERN (SYNC VOLTAGE HAS POWER LINE FREQUENCY)

5.6 AFC ALIGNMENT

Several AM receiver models employ automatic frequency control. The heart of this system is a discriminator stage, resembling the FM discriminator shown in Figure 5-5.

Proper connections for visual alignment of an afc discriminator are shown in Figure 5-10. Before undertaking alignment, capacitor C_2 must be disconnected temporarily, the avc circuit of the receiver interrupted (by connecting a temporary jumper from point A to ground), and the upper half of the discriminator load resistor short-circuited, as shown in Figure 5-10.

The frequency-modulated signal generator should be set to the intermediate frequency of the receiver and connected to the last if grid. Sync voltage output terminals of the generator are connected to the sync input of the oscilloscope.

Proper alignment of the discriminator will yield patterns of the type shown in Figures 5-8 and 5-9. See Section 5.5 for detailed instructions on discriminator alignment.

5.7 CHECKING AVC ACTION

Every present-day receiver, except simple tuned rf regenerative, and superregenerative sets, has an avc circuit. For best set performance, the avc circuit must operate properly. While avc circuits have been adjusted by means of a high-resistance dc voltmeter, the advantage of using an oscilloscope lies in the ability of this instrument to show avc distortion as well as whether or not avc "takes hold." The following 7-step method describes a simple and complete scheme for checking avc performance:

(1) Connect signal generator having known good

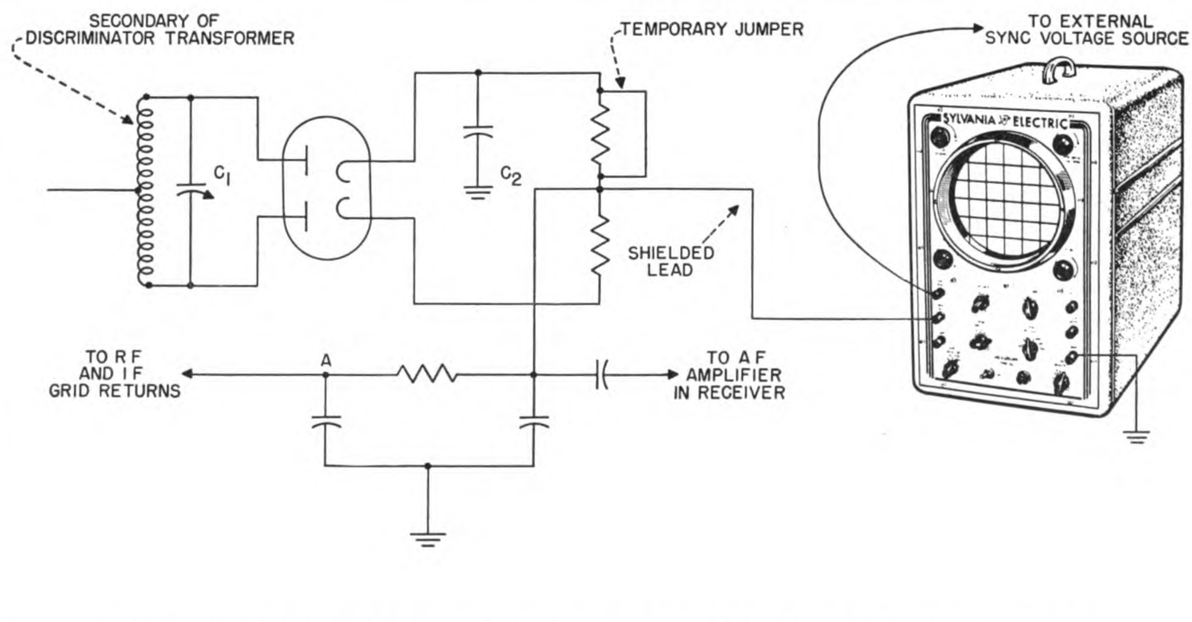


FIGURE 5-10 OSCILLOSCOPE CONNECTIONS FOR AFC DISCRIMINATOR ALIGNMENT

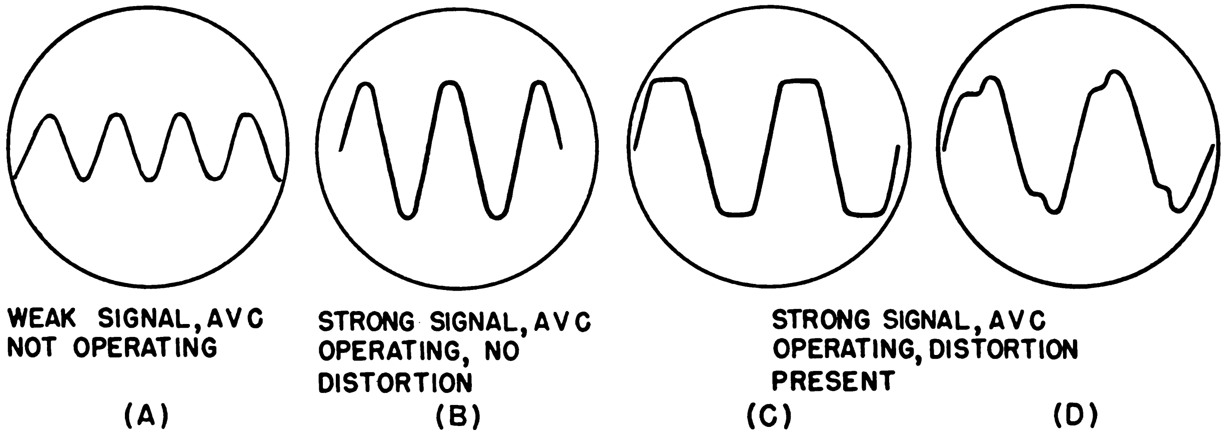


FIGURE 5-11 PATTERNS OBTAINED IN AVC TEST

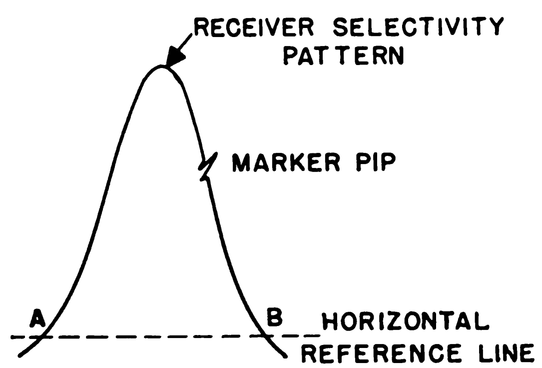


FIGURE 5-12 MARKER PIP ON SELECTIVITY CURVE

sine-wave output to antenna and ground terminals of receiver under test.

(2) Set signal generator modulation to 400 cycles.

(3) Set generator and receiver dials to a clear frequency preferably in broadcast band.

(4) Connect vertical input terminal of oscilloscope, by means of short, shielded lead to second detector output.

(5) Prepare oscilloscope as follows: (a) Set coarse and fine frequency controls to approximately 100 cycles, (b) set sync switch to INTERNAL, and (c) advance sync amplitude control about halfway.

(6) Adjust signal generator attenuator for low signal output, tune-in signal with receiver, and note that several cycles of modulating frequency appear on oscilloscope screen. Adjust vertical gain control for pattern height of about ½ inch, set frequency controls for about 4 cycles on screen, and adjust sync control to hold pattern stationary on screen. Pattern should have good sine wave form, similar to Figure 5-11(A).

(7) Advance generator attenuator setting gradually for higher signal output, noting that pattern height increases—rapidly at first, up to point at which avc action starts, after which little or no increase in height will result from further increase of signal input to receiver. At this point, pattern should be larger in size, as shown in Figure 5-11(B), but should have the same good waveform as originally. If wave is distorted, as in Figure 5-11(C), a defective component (such as open, shorted, or leaky capacitor) is present in avc circuit.

5.8 ESTABLISHING MARKER POINTS

Very often, when aligning a receiver visually, it is necessary to know the actual passband width of the selectivity curve (see Figure 5-3, (A) to (E)) in kilocycles.

Bandwidth sometimes may be determined from the setting of the sweep width control of the frequency-modulated signal generator, if the scale of this control has been calibrated accurately. However, an indication obtained in this manner usually will measure only the frequency width at the bottom of the skirts of the curve.

A more satisfactory method, which furnishes a legible "pip" (see Figure 5-12) that may be moved at will to any point on the curve, is illustrated by Figure 5-13. The scheme works this way: After the if ampli-

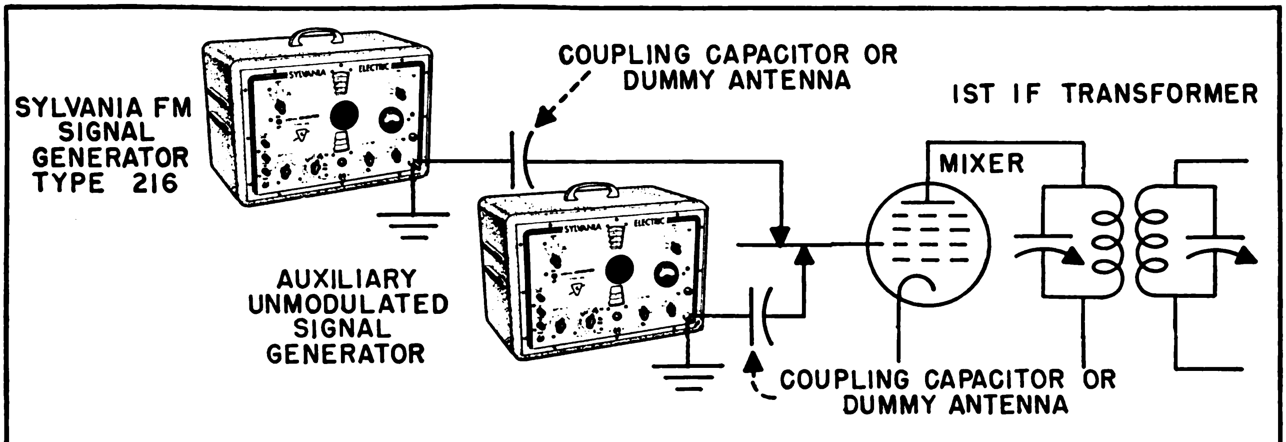


FIGURE 5-13 APPARATUS SETUP FOR PRODUCING MARKER PIPS ON SELECTIVITY CURVE

fier has been correctly aligned with an FM signal generator connected to the mixer control grid, apply a signal at the same time to the same grid from a second, unmodulated signal generator set to the intermediate frequency (see Figure 5-13).

As the second (auxiliary) signal generator is tuned above and below the intermediate frequency, the marker pip will travel around the curve pattern, being at some point on the left-hand slope of the curve at lower frequencies and on the right-hand slope at higher frequencies. The corresponding frequencies may be read from the dial settings of the auxiliary signal generator. Thus, if the pip is at point A when the auxiliary generator is tuned to 10.6 Mc and is at point B when the generator is tuned to 10.8 Mc, the bandwidth along the horizontal reference line is 10.8—10.6 or 0.2 megacycles.

Another method makes use of the intensity modulation input feature of the Sylvania Oscilloscope Type 132. The apparatus set-up is shown in Figure 5-14. The FM signal generator output is connected to the antenna and ground terminals of the receiver or to the if input, depending upon whether if selectivity or overall selectivity is to be observed.

The output of a pulse generator is connected to the intensity modulation input terminal of the Type 132 oscilloscope. This generator should deliver sharp, spiked positive pulses at a continuously variable repetition rate. The sharper and narrower these pulses, the brighter and finer will be the marker points obtained. However, not more than 2 volts should be applied to the cathode ray grid. For best stability at any repetition rate, the pulse generator may be synchronized with an external oscillator.

A typical selectivity curve (alignment pattern) punctuated by marker points obtained from a pulse generator is shown in Figure 5-15. A similar pattern, in which corresponding points are blanked out by pulses of opposite polarity, is shown in Figure 5-16.

To determine the frequency separation of the marker points along the selectivity curve, it is necessary only to read the pulse repetition frequency from the dial

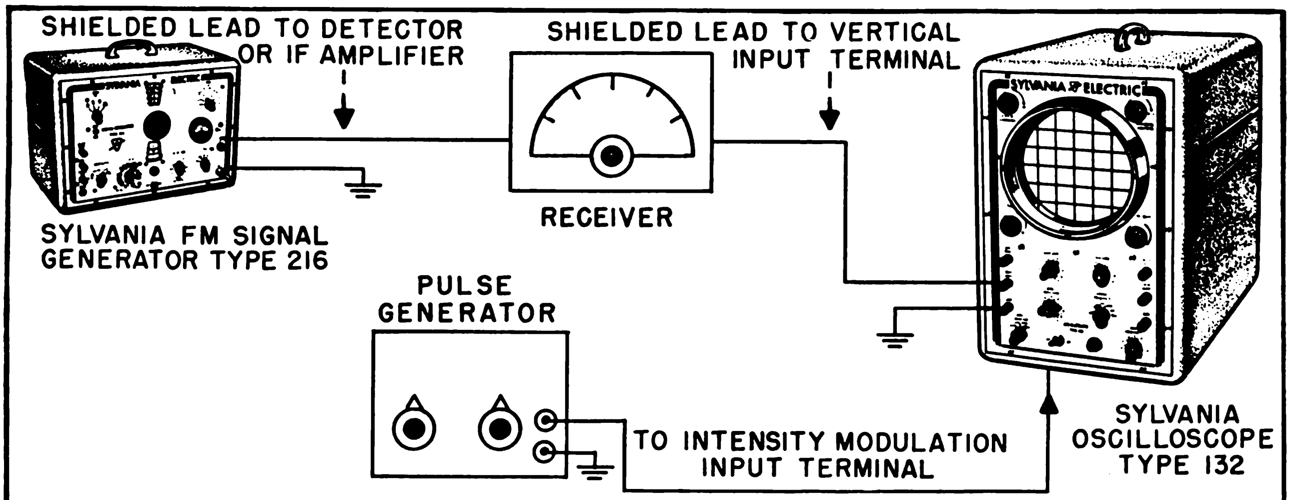


FIGURE 5-14 CONNECTIONS OF INSTRUMENTS FOR PRODUCING MARKER POINTS ON ALIGNMENT PATTERN

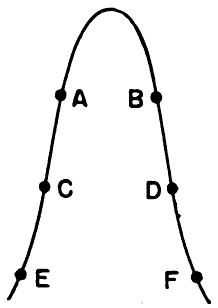


FIGURE 5-15 MARKER POINTS ON ALIGNMENT PATTERN

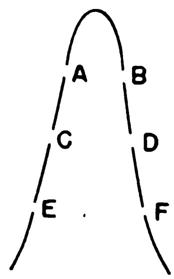


FIGURE 5-16 BLANKED-OUT POINTS ON ALIGNMENT PATTERN

of the pulse generator. Thus, if the repetition rate is 10,000 cycles, the points will be 10 kc apart along the curve.

Both of the marker systems explained in the foregoing paragraphs are applicable to complete (overall) receiver selectivity curves, as well as to if curves.

5.9 FINDING RECEIVER FAULTS FROM OSCILLOSCOPE PATTERNS

Aside from showing the state of receiver alignment, oscilloscope patterns also may reveal faults in receiver circuit operation. This makes the oscilloscope an ideal trouble-shooting tool in radio servicing.

Several typical patterns which are likely to occur in routine trouble shooting are shown in Figure 5-17. There are many variations of these images. A, B, E, and F are obtained with the oscilloscope set for sine-wave response with its vertical input terminals connected across the receiver voice coil. An amplitude-modulated signal is applied to the antenna and ground terminals of the receiver or a sine-wave audio signal is applied to the input circuit of the audio amplifier of the receiver. The oscilloscope pattern obtained should be a sine-wave pattern if the receiver circuit is operating satisfactorily and the signal levels are proper. Modulations of the type shown in Figure 5-17(A) and (B) are produced by, and indicate hum. How to locate the source of this hum and correct it is discussed in Section 5.10, step 3; in Section 6.3, step 4; and in Section 8.7. (E) and (F) show overloading of the audio amplifier which may be due to too high a signal at any point. Methods of isolating the cause of overloading are treated in Section 7.7 and Figure 6-3. Discovery, identification, and correction of distortion in radio receivers and audio amplifiers are discussed in Section 6.4 and 6.5.

Figure 5-17(C) and (D) are obtained with an FM signal generator connected for alignment, as outlined in Sections 5.1 and 5.2. These curves will be smooth, symmetrical, and single-lined when the receiver is operating correctly and signal levels are proper. A ragged modulation, such as that shown in Figure 5-17(C), almost always is due to noise or outside signal pickup. Occasionally, it indicates oscillation. Two irregular curves which cannot be made to merge into one (see Figure 5-17(D) indicate regenerating in the receiver. This condition sometimes is caused by connection of the oscilloscope and/or signal generator to the receiver, and often can be eliminated by shortening and shielding the external connections to the instruments.

Other fault patterns are shown in Figures 5-3(B), (C), (D), and (E) and are discussed in the text accompanying those illustrations.

The serviceman will discover that unusual modulations of any sort are an indication of the circuit trouble. By studying the shape and size of these distortions and comparing them with the waveforms given here he may identify the circuit trouble and localize it.

5.10 SIGNAL TRACING AND TROUBLE-SHOOTING OF RADIO RECEIVERS

The oscilloscope enables the radio serviceman to make dynamic tests on radio receivers. In this respect, the oscilloscope is an invaluable trouble-shooting tool. By means of dynamic tests, a receiver is checked for performance systematically under actual operating conditions, and circuit troubles may be localized more accurately and quickly than by haphazard tests not made under operating conditions. The oscilloscope also permits simplified signal tracing in radio receivers.

The following test equipment will be required for dynamic testing: (1) a complete oscilloscope, such as the Sylvania Type 131 or Type 132, (2) a modern signal generator or service test oscillator, such as the Sylvania Type 216 and (3) an audio oscillator, such as the Sylvania Type 145. The latter instrument may be omitted if the signal generator delivers separate 400-cycle output as does the Sylvania Type 216.

Prior to undertaking a dynamic test, the oscilloscope must be prepared for sine-wave patterns as follows:

(1) Set coarse and fine frequency controls for approximately 100-cycle sweep (the exact

frequency is not important, since a closer adjustment will be made later).

(2) Set sync switch to INTERNAL.

(3) Advance sync control about halfway.

(4) Advance horizontal gain control until horizontal line trace extends over most of screen center.

(5) Set focus and intensity controls for clear, sharp trace.

(6) Calibrate oscilloscope screen as explained in Section 4.6 and vertical gain control as explained in Section 4.7.

The "high" output leads of both the signal generator and audio oscillator must be provided with series capacitors rated at 0.05 μf to prevent damage to the instruments when they are connected into dc circuits.

5.11 TESTING AM SUPERHETS

A typical AM superheterodyne circuit with a straight ac power supply is shown in Figure 5-18. Various circuit points to which instruments will be connected during the test have been numbered. The following procedure is recommended for making the dynamic test:

(1) Switch-on receiver, detune its dial away from any interfering carrier, and reduce settings of rf and af gain controls to zero.

(2) Connect ground lead of signal generator to point 2 (chassis ground).

(3) Connect vertical input terminals of oscilloscope to 20 and 21. Advance vertical gain control about halfway. Horizontal straight-line trace should not alter. If line becomes badly rippled or toothed, hum or noise is present in audio stages (V_5 and/or V_6). Some ripple usually will be observed with the best of receivers, since ac power supplies do not deliver entirely perfect dc. However, this ripple should not exceed a reasonable amount; that is, in a good receiver not more than 1 screen division on the Sylvania Type 131 Three-Inch Oscilloscope, or more than 2 divisions on the Type 132 Oscilloscope, when the vertical gain control is set to maximum.

(4) Apply 400-cycle signal to 18 and 19. If speaker cable is in good condition, several complete cycles will appear on screen. Set frequency and sync amplitude controls to obtain four or five *stationary* cycles. Set vertical gain control for pattern height of about ½ inch.

(5) Connect ground lead of audio oscillator (if used in Step 4) to 2.

(6) Apply 400-cycle signal to 17. Advance vertical gain control, if necessary, to restore pattern height. Read voltage output on calibrated oscilloscope screen. If current continuity is perfect, disappearance of pattern, or distortion of sine wave shape, indicates defective transformer T_6.

(7) Apply 400-cycle signal to 16. Loss or distortion of pattern indicates defective tube V_6.

(8) Apply 400-cycle signal to 15. Loss of pattern indicates open capacitor C_A, or a coupling lead open-circuit.

(9) Apply 400-cycle signal to 13. Slowly advance af gain control, noting that sine-wave pattern on screen increases in height as gain control is advanced toward maximum. Loss of pattern at this point indicates defective af gain control potentiometer, open coupling capacitor C_B, or defective pentode section of tube V_5. (Do not advance gain control to point where tops of cycles begin to flatten off, indicating overloading of the 1st or 2nd audio stage, or both.) Distortion of pattern indicates defective tubes V_5 or V_6, incorrect tube voltages, or defective or improperly-sized resistors or capacitors in V_5 and V_6 circuits.

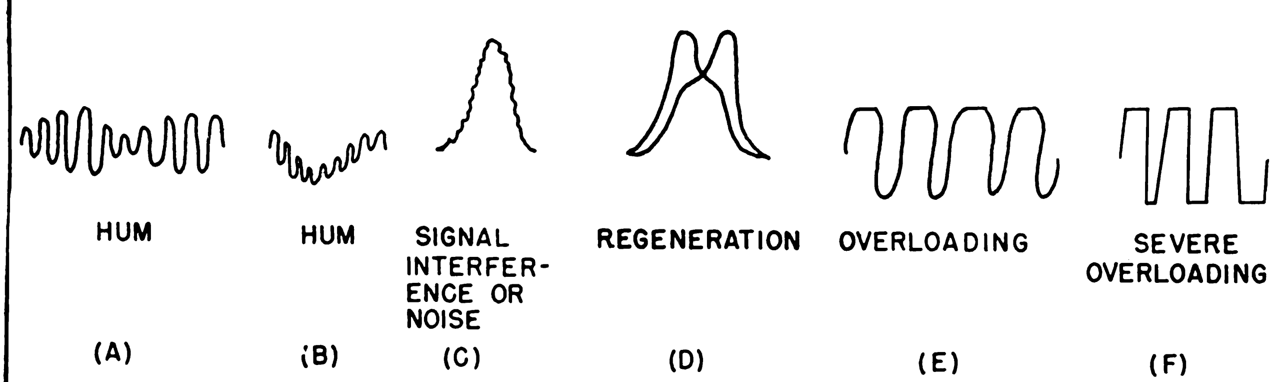


FIGURE 5-17 COMMONLY-ENCOUNTERED PATTERNS SHOWING RECEIVER TROUBLES

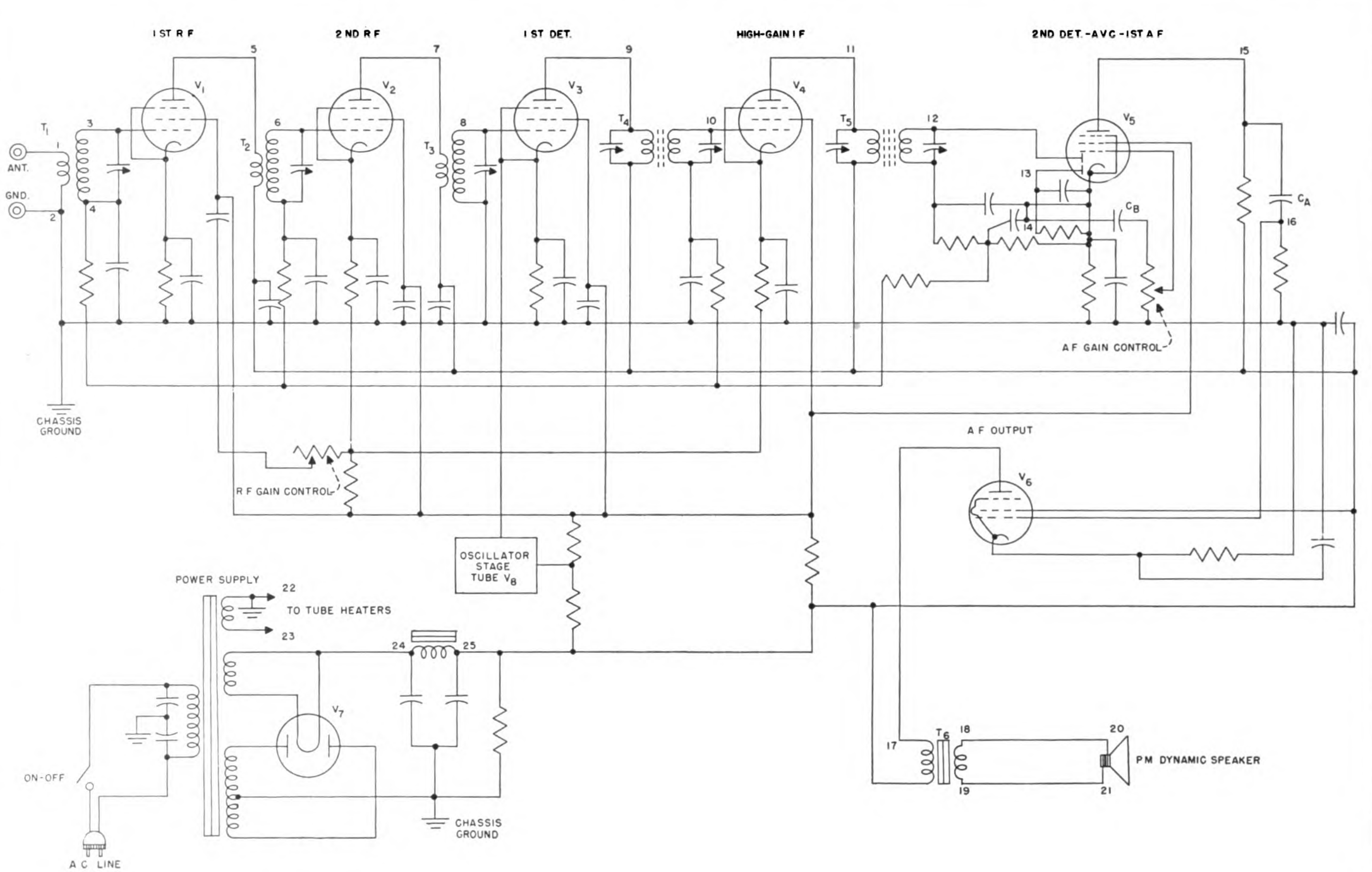


FIGURE 5-18 AC SUPERHETERODYNE, SHOWING CIRCUIT POINTS FOR DYNAMIC ANALYSIS

(10) Interrupt avc by connecting temporary jumper from 13 to chassis.

(11) Apply 400-cycle-modulated if signal to 12. Adjust vertical gain control, if necessary, to restore pattern height. Loss of pattern at this point indicates defective diode section in tube V_5, or defective components in 2nd detector circuit.

(12) Apply modulated if signal to 11 and adjust trimmers of transformer T_5 for peak height of pattern. Loss of pattern indicates defective if transformer T_5.

(13) Apply modulated if signal to 10. Advance rf gain control about halfway, and readjust T_5 trimmers. Loss of pattern indicates defective tube V_4, absent or incorrect tube voltages, or defective resistors or capacitors in if circuit.

(14) Apply modulated if signal to 9. Adjust trimmers of transformer T_4 for peak height of pattern. Loss or distortion of pattern indicates defective if transformer T_4. If tops of cycles on screen begin to flatten out, indicating overloading, reduce signal output of generator, reduce setting of rf gain control, or both.

(15) Apply modulated if signal to 8. Readjust T_4 trimmers. Readjust vertical gain control if necessary. Loss of pattern indicates defective tube V_3; loss of, or incorrect tube voltages; defective 1st detector circuit components; or dead or misaligned oscillator V_8.

(16) Apply modulated 1000-kc signal to 7. Tune receiver dial for peak pattern height at 1000 kc. Loss of pattern indicates defective detector input transformer T_3.

(17) Apply modulated 1000-kc signal to 6. Increase in pattern height indicates voltage gain of 2nd rf stage. Loss of pattern indicates defective tube V_2; loss of, or incorrect tube voltages; or defective 2nd rf circuit components.

(18) Apply modulated 1000-kc signal to 5. Increase in pattern height indicates step-up ratio of rf transformer T_2. Loss of pattern indicates defective transformer T_2.

(19) Apply modulated 1000-kc signal to 3. Increase in pattern height indicates voltage gain of 1st rf stage. Loss of pattern indicates defective tube V_1; loss of, or incorrect tube voltages; or defective 1st rf circuit components.

(20) Apply modulated 1000-kc signal to 1. Increase in pattern height indicates step-up ratio of antenna input transformer T_1. Loss of pattern indicates defective transformer T_1.

(21) With signal generator still connected to point 1, set generator to 1500 kc and to 600 kc, retune receiver to those frequencies, and check overall alignment carefully, as explained in Section 6.1

(22) Remove jumper from point 13, and check avc action as instructed in Section 5.7.

5.12 TESTING FM RECEIVERS

The procedure for dynamic analysis of an FM receiver will be very much the same as just outlined for an AM superheterodyne, except that a frequency modulated signal generator must be employed. The FM signal is applied to the rf, 1st detector (mixer), if, and discriminator stages. A 400-cycle audio-frequency signal is applied to the af stages for test, and then removed before undertaking tests with the FM signal. The oscilloscope must be synchronized at the sweep rate of the generator, and its frequency controls must be adjusted to give a screen image of several cycles of the sweep generator frequency.

In the dynamic analysis of either AM or FM receivers, the pattern on the oscilloscope screen should not become very noticeably distorted at any point in the tests. If the preceding stage-by-stage procedure is followed, such distortion can be traced to the stage under test, where components may be replaced or adjusted to correct the trouble.

5.13 TESTING POWER SUPPLIES

To check effectiveness of the receiver power supply filter in removing ripple from the dc output voltage, follow this procedure: (1) With oscilloscope frequency controls set to approximately 20 cycles, sync switch to LINE FREQ, and other controls as recommended in the 3rd paragraph in Section 5.10, connect vertical input terminals to chassis ground and point 24. Connect a 0.25 μf, 600-volt capacitor in series with the "high" vertical input terminal to protect oscilloscope from high dc voltage.

(2) Adjust vertical gain control for ripple pattern height of about 1½ inch.

(3) Transfer vertical input lead to 25, noting reduction of pattern height. If filter is very effective, nearly all ripple will disappear at point 25 and original horizontal straight-line trace will be resumed. If little or no reduction in ripple pattern height is observed as vertical input is transferred from 24 to 25, filter is not operating efficiently, and filter choke and capacitors should be inspected.

Further hum analysis steps are outlined in Chapter 6.

CHAPTER VI

USE OF THE OSCILLOSCOPE IN AUDIO AMPLIFIER TESTING

6.1 SIGNAL TRANSMISSION TEST IN SINGLE AMPLIFIER STAGE

An oscilloscope may be used with an audio oscillator to determine if an af signal is transmitted by an amplifier stage. By observing both input and output signals on the oscilloscope screen, the serviceman can note presence or absence of amplification. Also, distortion and outside modulation (introduced by hum, noise, or oscillation in the amplifier stage) may be detected. The single amplifier stage test is the basis of the *complete* amplifier test, as will be seen later in this chapter. However, the chief purpose of the transmission test is to determine if the amplifier is working.

The setup of apparatus for making this test is shown in Figure 6-1. Best results will be obtained with an audio oscillator, such as the Sylvania Type 145, having good sine wave output. A 0.1-µf fixed capacitor, C_1, is connected in series with the short, shielded oscillator output lead to protect the oscillator output transformer from dc voltages in the amplifier. Both oscillator and oscilloscope "exploring" leads may be terminated with clip-type test prods for quick connection to the numbered circuit points.

The test is made in the following manner: (1) Prepare oscilloscope for sine-wave patterns by setting frequency controls to approximately 200 cycles, sync switch to INTERNAL, sync amplitude control to one-half maximum, horizontal gain control to give long

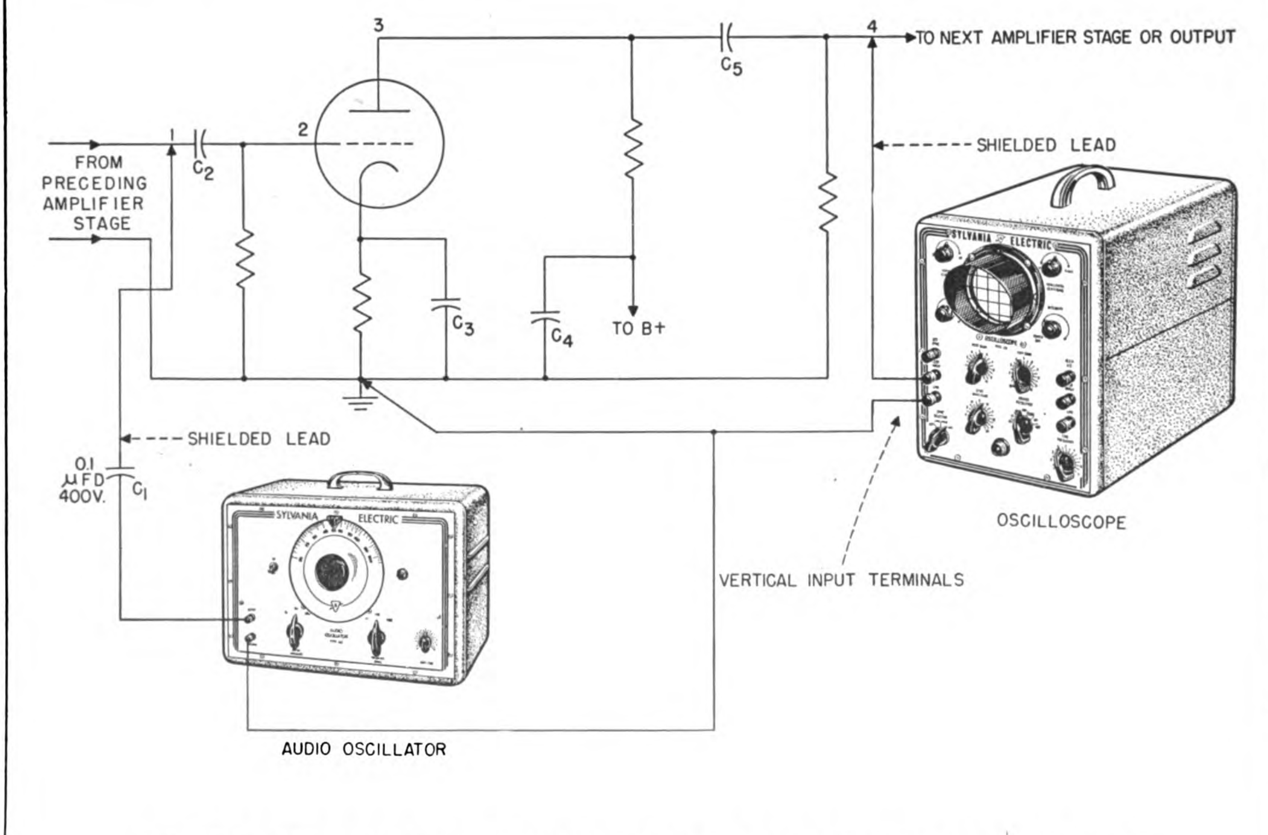


FIGURE 6-1 SETUP FOR SIGNAL TRANSMISSION TEST IN SINGLE AUDIO AMPLIFIER STAGE

horizontal line trace on screen, and vertical gain control to zero.

(2) Set audio oscillator to 1000 cycles. Set oscillator output control to zero.

(3) Couple oscillator, as shown in Figure 6-1, to point 2. Connect oscilloscope also to point 2.

(4) Advance oscillator output control slightly to trial setting.

(5) Advance vertical gain control (and oscillator output control, if necessary) until sine wave pattern has overall height of 2 screen divisions. Set frequency control for 5 complete cycles, and sync amplitude control to lock image on screen.

(6) Transfer vertical input lead to point 3. Pattern height should increase, indicating voltage gain of tube. Sine wave should not become distorted.

(7) Transfer vertical input lead to point 4. Loss of pattern indicates open capacitor C_6.

(8) With vertical input lead at point 4, transfer oscillator to point 1. Loss of pattern indicates open capacitor C_2.

(9) With oscillator connected to point 1, vertical input lead may be switched back and forth between 1 and 4. Resulting difference in pattern height indicates voltage gain of amplifier stage. If oscilloscope screen and vertical gain control have been calibrated (see Sections 4.6 and 4.7), corresponding gain may be read directly as difference between input (point 1) and output (point 4) voltages.

(10) At no step in this test should the waveform of the output voltage look much different from the sine-wave of the input voltage. Any change of the waveform itself indicates faulty transmission—either distortion, hum or noise. Distortion is discussed in Section 7.4 and 7.5; hum in Section 7.3.

(11) The transmission test may be repeated at other frequencies, such as 100, 500 and 10,000 cycles.

(12) The setup of apparatus for making a similar check of an entire amplifier, rather than a single audio stage, is shown in Figure 6-2.

6.2 MEASUREMENT OF VOLTAGE GAIN

As a sensitive ac voltmeter for voltage gain measurements in an audio amplifier, the oscilloscope offers the advantages of high input impedance, good frequency response, wide voltage range, and the ability to show waveform as well as amplitude of a voltage. Voltage gain may be measured in a single amplifier stage or through a complete multi-stage amplifier.

For voltage gain measurements, use the same apparatus setup shown in Figure 6-1 or 6-2, and prepare the oscilloscope according to the instructions given in step 1 of Section 6.1. Calibrate the vertical gain control and the oscilloscope screen as outlined in Section 4.6 and 4.7.

Determination of Voltage Gain of a Single Stage:

(1) Connect oscillator and vertical input terminals of oscilloscope to point 1 (see Figure 6-1).

(2) Set oscillator to 400 cycles. Set oscillator output control and vertical gain control for sine-wave pattern with overall height of about 2 screen divisions. Set sync amplitude control to lock image on screen. Record voltage, read voltage from oscilloscope screen and vertical gain control setting and record it as E.

(3) Transfer vertical input lead to point 4. Record new voltage, indicated by taller image on screen, as E_2.

(4) Determine voltage gain from the formula:

$$\text{V. G.} = \frac{E_2}{E_1}$$

(5) Repeat measurement at as many frequencies as desired.

Determination of Voltage Gain of Several Cascaded Stages:

(1) Proceed as when checking gain of single stage, except connect audio oscillator to input of first stage.

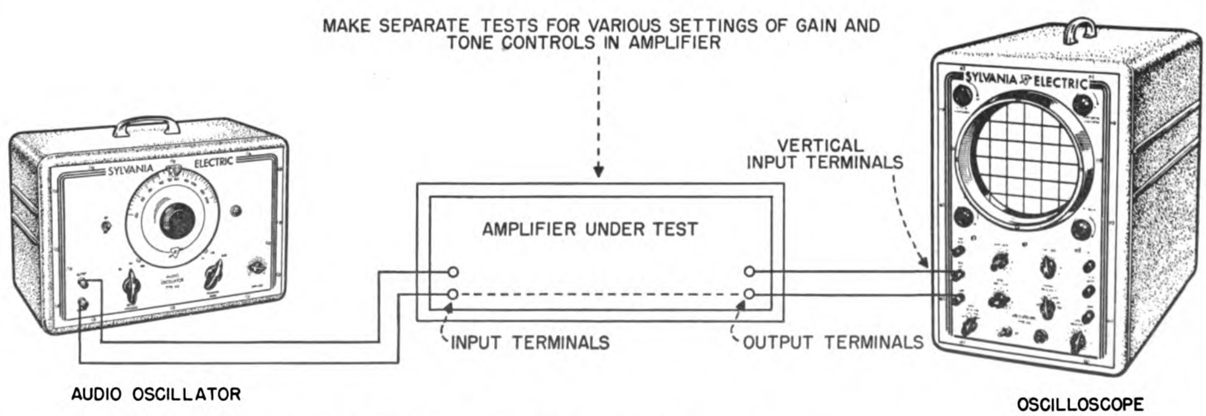


FIGURE 6-2 SETUP FOR TRANSMISSION TEST ON COMPLETE AUDIO AMPLIFIER

(2) Connect vertical input terminal of oscilloscope to input of first stage to determine value of E_1, then to output of last stage to determine value of E_2. Reduce setting of oscillator output control if cycles of pattern flatten out on tips, indicating signal overloading.

(3) Determine voltage gain from the formula:

$$V.G. = \frac{E_2}{E_1}$$

(4) Repeat measurement at as many frequencies as desired.

To determine the voltage gain in *decibels*, for either single stages or complete amplifiers, use the formula:

$$db = 20 \log_{10} \frac{E_2}{E_1}$$

When measurements are made on a multi-stage amplifier, repeat the tests for each setting of the amplifier tone control and for various settings of the amplifier gain control.

6.3 LOCATING HUM

Hum interference is of major concern equally to the amplifier designer and serviceman. Hum voltages usually are of power-line frequency when due to defective tube cathodes, heater-cathode short circuits, etc., and are of twice the line frequency (and sometimes higher multiples) when due to defective power supply filter action.

Several methods have been suggested, and are in regular use for locating and identifying hum with an oscilloscope. The authors have reviewed and tested all of these common methods of hum tracing in audio amplifiers and believe the following test will be found simple, rapid, and understandable.

(1) Prepare oscilloscope: (a) Set coarse and fine frequency controls for sweep frequency of about 20 cycles. *Exact* setting is unimportant here, since close frequency adjustment will be made in Step F. (b) Set sync switch to LINE FREQ. (c) Set sync amplitude control to about one-half maximum. (d) Set horizontal gain control for long horizontal line trace on screen. (e) Set vertical gain control to about one-half maximum. (f) Feed line-frequency signal into vertical input terminals (this signal may be obtained from the 6.3-volt output terminal of Sylvania Type 131 and 132 Oscilloscopes), and set fine frequency control, sync amplitude control, and vertical gain control for single, *stationary* cycle on screen. After adjustment is completed, remove line-frequency signal source from vertical input terminals.

(2) Switch-on amplifier to be tested, and set amplifier gain control to maximum. *Do not feed a signal into amplifier.*

(3) Connect grounded vertical input terminal of oscilloscope to chassis (or B-minus point) of amplifier. Connect a shielded test lead, terminated with a shielded test prod, to high vertical input terminal.

(4) Starting at input end of amplifier, touch vertical test prod successively to control grid and plate terminal of each tube until amplifier output terminals are reached. If no hum is encountered, horizontal line trace on oscilloscope screen will not be distorted. A line-frequency hum at any test point will cause one cycle to appear on screen. A hum signal having twice the line frequency will cause two complete cycles to appear. Three cycles will indicate hum interference at 3 times the line frequency, and so on. The advantage of this test is that the hum may be detected immediately in the *first* amplifier stage in which it occurs if the operator moves stage-by-stage from input to output of the amplifier. After the hum has been localized and its frequency determined, components and voltages then may be checked in the offending stage to correct the trouble.

Common causes of line-frequency hum are
(1) ungrounded or bypassed tube heaters.
(2) unbypassed power line.
(3) heater-cathode short-circuit inside or outside of tube.
(4) defective tube cathode.
(5) grid-cathode short-circuit.
(6) heater wiring too near control grid lead, and
(7) open grid resistor.

Common causes of hum at harmonics of the line frequency, especially the 2nd harmonic (twice line frequency), are
(1) shorted filter choke.
(2) filter choke too small.
(3) open filter capacitor, and
(4) filter capacitor too low in capacitance.

The operator must use judgment in making a hum test, since some hum interference will be found in the very best amplifiers. Amplifier manufacturers usually state the guaranteed maximum hum level in millivolts or decibels below maximum amplifier output.

6.4 DISTORTION MEASUREMENTS WITH SINE WAVES

One of the advantages of the oscilloscope as an output indicator is its ability to show the actual waveform of output voltages. In the case of an audio-frequency amplifier under test, a reasonably pure sine wave signal may be applied to the amplifier input, but the output voltage almost never is a sine wave of equal purity. The output wave is found to be a *complex wave* that is a distorted wave made up of a combination of the applied signal frequency and one or more harmonic frequencies. This complex wave pattern is seen on the oscilloscope screen. When a sine-wave signal is passed through an electrical net-

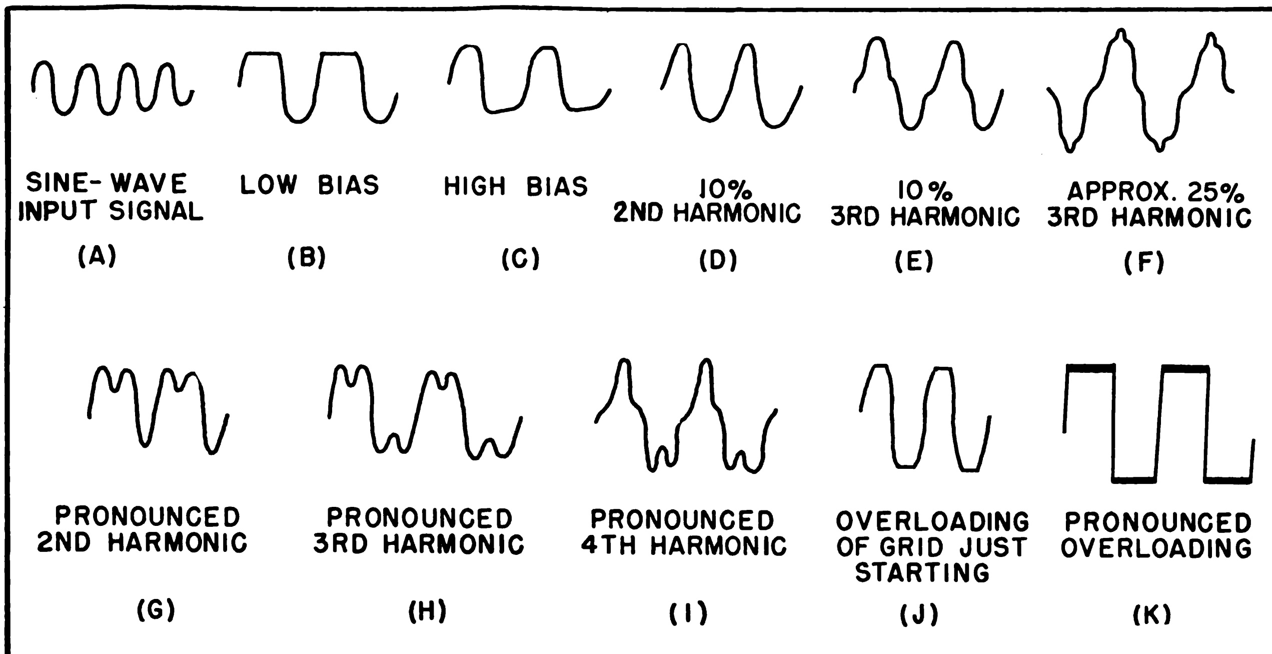


FIGURE 6-3 FAMILIAR DISTORTION PATTERNS OBTAINED IN AUDIO AMPLIFIER TESTING

work which is not an amplifier, similar distortion occurs.

Any measurement of the extent to which the output waveform varies from the pure sine-wave input signal is a distortion measurement. Distortion tests may be performed on single amplifier stages or upon a complete multi-stage amplifier.

Most amplifier servicemen will be concerned with whether or not distortion is present at all, and to what extent it is corrected by their repair operations. When making distortion tests at any audio frequency, undistorted sine-wave signal is fed into the amplifier input circuit, and the waveform of the output voltage is examined by means of the oscilloscope set for stationary sine-wave patterns and connected to the amplifier output terminals. Some of the output patterns resulting from various sorts of distortion are given in Figure 6-3.

The patterns shown in Figure 6-3 (B to K) are typical of those usually encountered when a sine-wave signal (Figure 6-3(A)) is fed into the amplifier input terminals. In ordinary amplifier work, the 2nd, 3rd and 4th harmonics usually are the only distortion components of concern to the serviceman. The old harmonics (3rd, 5th, etc.) produce symmetrical distortion of the sine wave; that is, both positive and negative peaks are altered so that one is a "mirror image" of the other. (See E, F, H, J and K in Figure 6-3.) Even harmonics (2nd, 4th, etc.), on the other hand, alter the sine wave asymmetrically, so that one side of the waveform looks different from the other, as shown in B, C, D and G in Figure 6-3.

Various other distortion patterns resembling those shown in Figure 6-3 may be obtained in audio amplifier tests. They may be more or less exaggerated than those shown here, indicating more or less distortion than that indicated by patterns in Figure 6-3. Also, various phase changes acting upon the signal and its harmonics as they pass through the amplifier under test may alter these patterns somewhat from the shapes given here. But, in general, the patterns given in Figure 6-3 are typical and common and, when thoroughly learned, will be of considerable service to the amplifier serviceman.

6.5 DISTORTION MEASUREMENTS WITH SQUARE WAVES

Square waves offer the serviceman a means whereby the entire overall operation of an audio amplifier may be known quickly and completely. The principle underlying this test is simple: A square wave signal (see Figure 6-5(A)) is applied to the input of the amplifier under test. The output voltage delivered by the amplifier then is examined with an oscilloscope. If overall response of the amplifier is uniform and efficient, a square wave output signal will be observed. If the amplifier is not operating entirely efficiently, the squareness of the output signal will be destroyed in one way or another. Response of the amplifier may be interpreted from the shape of the output wave.

Instruments required for this test are

(1) a square wave generator, and

(2) a complete oscilloscope.

The setup of apparatus for the square wave test is shown in Figure 6-4.

The square wave test is made in the following manner:

(1) Set frequency control of square wave generator to the desired test frequency (60 cycles will be a good initial frequency) and connect

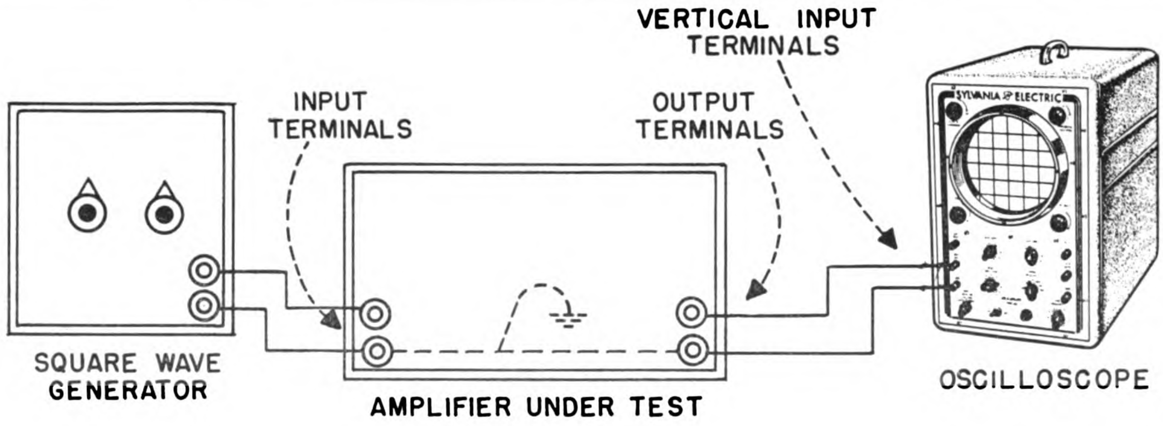


FIGURE 6-4 SETUP FOR SQUARE-WAVE TESTING OF AUDIO AMPLIFIER

generator output terminals to input terminals of amplifier under test.

(2) Set oscilloscope frequency controls to frequency of square wave generator. Set sync control to INTERNAL, and sync amplitude control to about ½ maximum. Set horizontal gain control for long horizontal line trace. Set vertical gain control to zero.

(3) Connect vertical input terminals of oscilloscope to amplifier output terminals.

(4) Slowly increase settings of generator output control and vertical gain control for reasonably high pattern on oscilloscope screen. Set oscilloscope frequency controls and sync amplitude control for several stationary "cycles" on screen. Note appearance of pattern and compare with patterns B to E in Figure 6-5, for interpretation.

(5) Repeat tests at several square wave frequencies and at various settings of amplifier gain and tone controls.

6.6 CHECKING FREQUENCY RESPONSE

In amplifier testing, especially in the absence of a square wave generator, it often is desirable to check the overall frequency response of a single amplifier stage or of a complete amplifier. Instruments required for this test are (1) a good-grade variable-frequency sine-wave audio oscillator, such as the Sylvania Type 145, and (2) a complete oscilloscope. The apparatus setup is shown in Figure 6-6. The test procedure is to

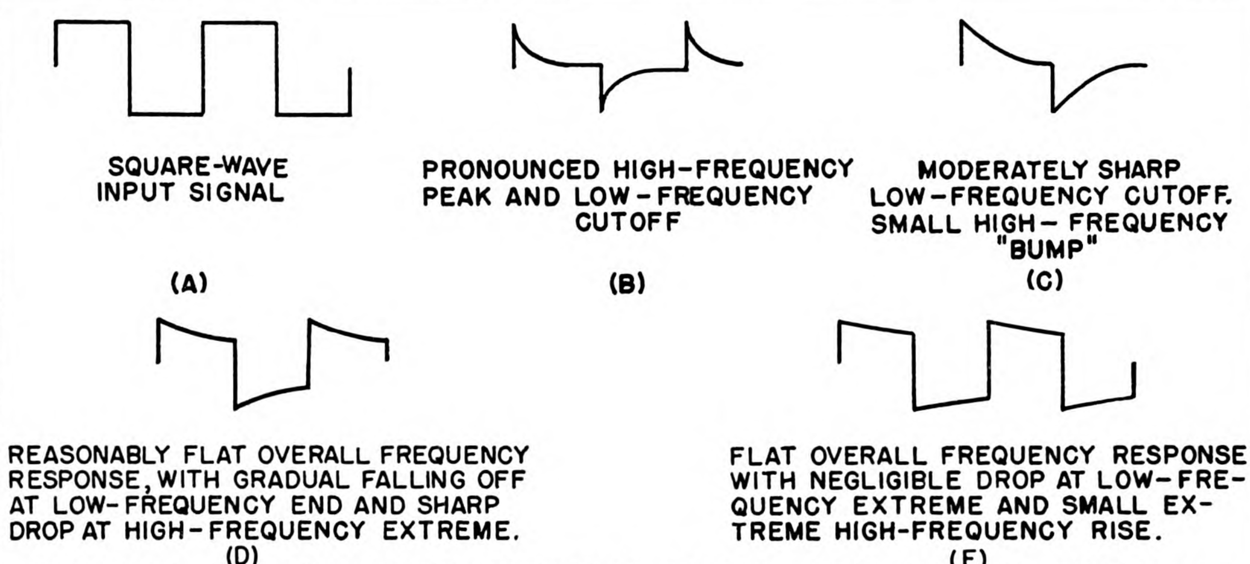


FIGURE 6-5 FAMILIAR RESPONSE PATTERNS OBTAINED IN SQUARE-WAVE TESTING OF AUDIO AMPLIFIERS

measure the amplifier output voltage at a number of frequencies throughout the audio-frequency range *using* a constant value of signal voltage. The oscillator supplies the signal voltage, and the oscilloscope *is* employed to check both input and output voltages. The changeover switch permits switching of the high vertical input terminal from input to output of the amplifier to check these two voltages. If the oscillator is known to have a constant voltage output a quick, easy check can be made without the changeover switch by running through the audio frequency band observing the change in the height of the trace. To make a more careful check, the following procedure is suggested:

(1) Prepare the oscilloscope:
   (a) After calibrating screen and vertical gain control (see Section 4.6 and 4.7), set frequency controls to approximately 20 cycles;
   (b) set horizontal gain control for long horizontal line trace;
   (c) set sync switch to INTERNAL;
   (d) set sync amplitude control to ½ maximum, and
   (e) set vertical gain control to zero.

(2) Switch-on amplifier, and set its gain control to maximum and tone control to center or "mellow" position.

(3) Set oscillator to 20 cycles.

(4) Throw changeover switch to position A. Adjust oscillator output control and oscilloscope vertical gain control for pattern height of 2 screen divisions.

(5) Throw changeover switch to position B and adjust amplifier gain control for convenient pattern height. Do not touch oscillator output control or oscilloscope vertical gain control. Read voltage from pattern height and record this voltage against 20 cycles.

(6) Set oscillator to 75 cycles. Throw changeover switch to position A. Readjust oscillator output control for 2-division pattern height.

(7) Throw changeover switch to position B and read output voltage, on oscilloscope screen, for 75 cycles.

(8) Repeat procedure at 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 5000 and 10,000 cycles. At each new frequency, reset signal voltage to same 2-division amplitude by throwing changeover switch to position A and adjusting oscillator output control.

(9) Plot each output voltage value against corresponding frequency, to obtain response curve.

(10) For a complete inspection, plot several response curves showing frequency response of amplifier for each setting of tone control and several settings of amplifier gain control.

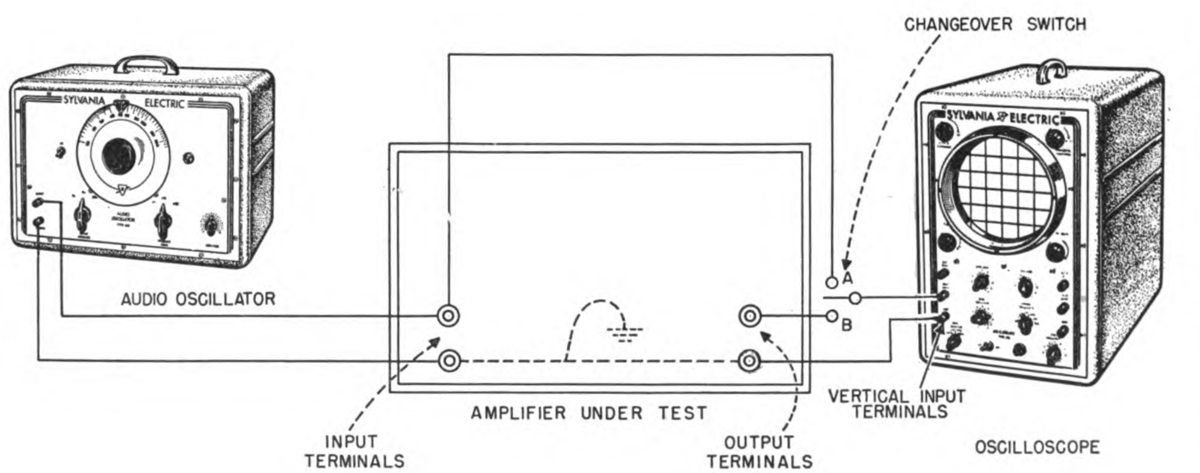


FIGURE 6-6 SETUP FOR CHECKING FREQUENCY RESPONSE OF AUDIO AMPLIFIER

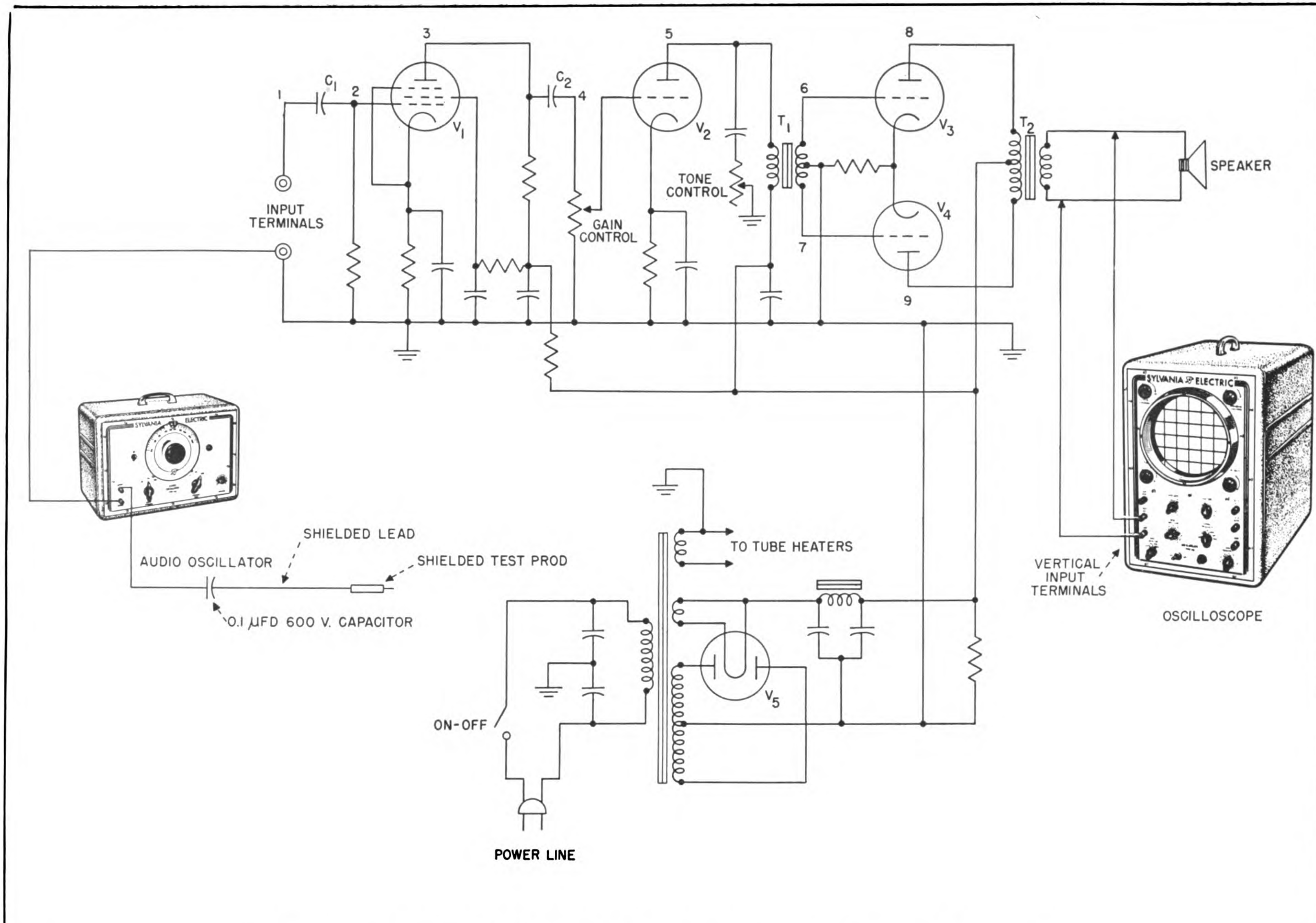


FIGURE 6-7 SETUP FOR SIGNAL TRACING (CHANNEL ANALYZING) IN AUDIO AMPLIFIER

6.7 SIGNAL TRACING IN AUDIO AMPLIFIER

Signal tracing is as important a dynamic test in amplifier trouble shooting as in receiver testing. The oscilloscope is unequaled as the indicating device in amplifier signal tracing, since it shows not only presence or absence of the signal in each amplifier stage, but shows quickly and simply the amplitude and waveform of the signal as well.

The apparatus setup for amplifier signal tracing is shown in Figure 6-7. A typical audio amplifier circuit is shown. Using this equipment, there are two ways to trace signals through the amplifier. The first method consists of permanently connecting the vertical input terminals of the oscilloscope to the amplifier output terminals, as shown in Figure 6-7, and applying an audio signal successively to the various amplifier stages, starting at the output stage and working back to the input stage. The second method consists of connecting the audio oscillator permanently to the amplifier input terminals and connecting the vertical input terminals of the oscilloscope successively to various circuit points, starting at the input stage and working forward progressively to the output stage. Both methods accomplish the same result and neither is recommended as superior to the other. For purposes of explanation here, however, we have chosen the first method. Consequently, the audio oscillator is shown in Figure 6-7 provided with a shielded output prod by means of which the audio signal may be applied to the various numbered circuit points.

Prior to tracing the signal, prepare the oscilloscope according to the instructions given in Step 1 in Section 6.6, and set the audio oscillator to 1000 cycles. Connect the apparatus as shown in Figure 6-7 and allow amplifier to warm up.

(1) Apply audio signal to point 8. Adjust oscillator output control and vertical gain control for sine-wave pattern about 2 screen divisions high. Set sync amplitude control to lock pattern on screen. No pattern indicates defective transformer T_2.

(2) Apply audio signal to 9. No pattern indicates open lower half of primary transformer T_2.

(3) Apply audio signal to 6. Loss or distortion of pattern indicates defective tube V_3, loss of tube voltages, incorrect voltages or defective cathode resistor.

(4) Apply audio signal to 7. Loss or distortion of pattern indicates defective tube V_4, loss of tube voltages, incorrect voltages, or defective cathode resistor.

(5) Apply audio signal to 5. Increased pattern height indicates step-up ratio of transformer T_1; decrease of pattern height indicates step-down ratio. No increase indicates 1-to-1 ratio. Run tone control through range to study its operation. Loss of pattern indicates shorted tone control capacitor or defective transformer T_1.

(6) Apply audio signal to 4. Run gain control through range to determine if it is operating properly (pattern height should increase as gain control is advanced). Finally set gain control for desirable pattern height. Loss of pattern indicates defective tube V_2, loss of tube voltages, incorrect voltage, or defective components in V_2 circuit. Distortion of pattern indicates incorrect tube voltages, or defective or improperly-sized components in V_2 circuit.

(7) Apply audio signal to 3. Loss of pattern indicates open capacitor C_2.

(8) Apply audio signal to 2. Increased pattern height indicates voltage gain supplied by tube V_1. Loss of pattern indicates defective tube V_1, loss of tube voltages, incorrect voltages, or defective components in V_1 circuit. Distortion of pattern indicates defective tube V_1, incorrect tube voltages, or defective or improperly-sized components in V_1 circuit.

(9) Apply audio signal to 1. Loss of pattern indicates open capacitor C_1.

CHAPTER VII

USE OF THE OSCILLOSCOPE IN TRANSMITTER TESTING

7.1 MODULATION CHECKING WITH WAVE PATTERNS

The cathode ray oscilloscope is particularly useful for observing and measuring modulation percentage of the amplitude modulated transmitters. In this application, the oscilloscope is superior to modulation monitors employing d'Arsonval meters, since the electron beam can follow the most rapid modulation peaks without lag. Commercial and amateur transmitters operating on any carrier frequency may be checked. For modulation checking, either wave patterns (see Figure 7-3) or trapezoidal pattern (see Figure 7-4) may be employed.

Instrument connections for modulation checking by means of wave patterns are shown in Figure 7-1. Here, the *direct* vertical input must be employed. Do not use the vertical amplifier, since it will not pass the transmitter carrier frequency efficiently. The linear sweep frequency is set to 50 or 100 cycles, sync switch to INTERNAL. Horizontal gain control is set for a long, horizontal line trace in the absence of an applied carrier (see Figure 7-3(A)). The sync amplitude control is set to prevent drift of the modulation pattern across the screen.

Figure 7-3 (C), (D) and (E) gives modulation patterns for under-modulation and overmodulation, and 100% modulation. Figure 7-5(A) gives the method of computing *any* modulation percentage from wave patterns. For modulation checking, a sine-wave audio oscillator may be employed to modulate the transmitter—or the operator may whistle a sustained note into the microphone.

7.2 MODULATION CHECKING WITH TRAPEZOIDAL PATTERNS

Figure 7-2 shows the apparatus setup and transmitter connections for modulation checking by means of trapezoidal patterns. Here, as in the preceding method, the *direct* vertical input connection of the oscilloscope is employed. Do not use the vertical amplifier. The linear sweep oscillator is switched-off and the vertical gain control set to zero.

Trapezoidal modulation patterns for under-modulation, overmodulation and 100% modulation are

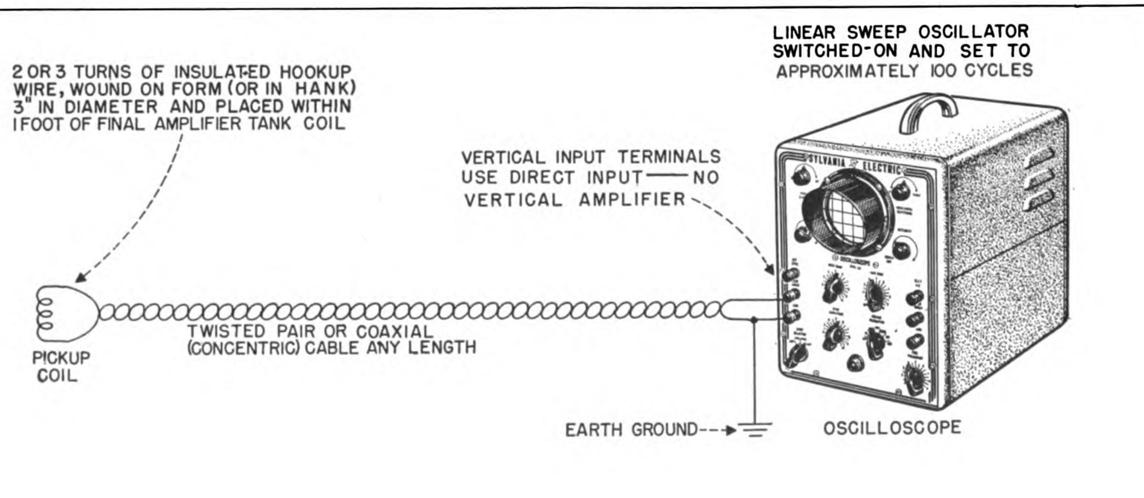


FIGURE 7-1 OSCILLOSCOPE CONNECTIONS FOR WAVE-TYPE MODULATION PATTERNS

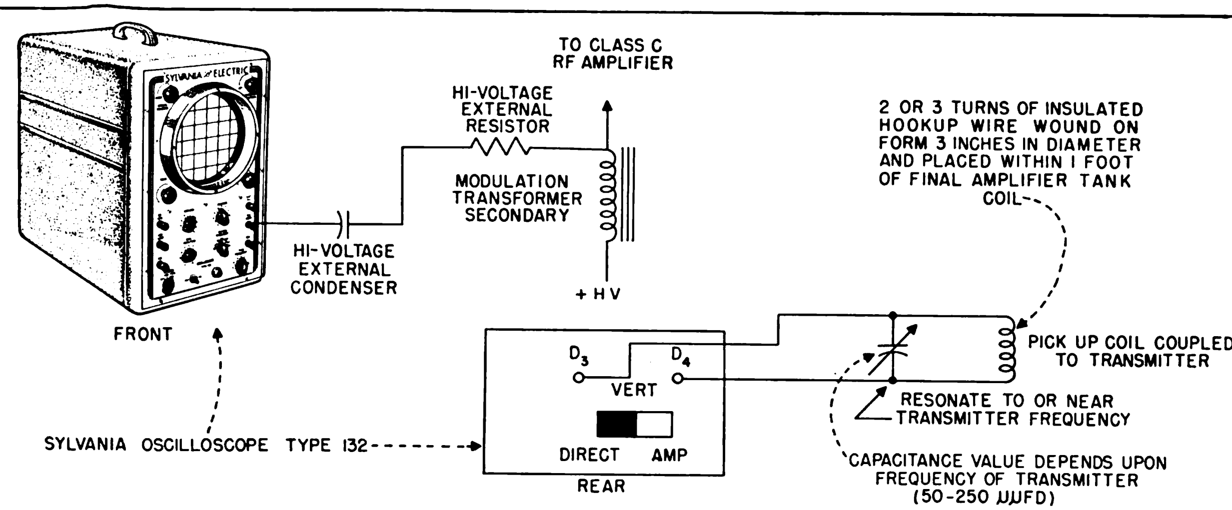


FIGURE 7-2 OSCILLOSCOPE CONNECTIONS TO TRANSMITTER FOR TRAPEZOIDAL MODULATION PATTERNS

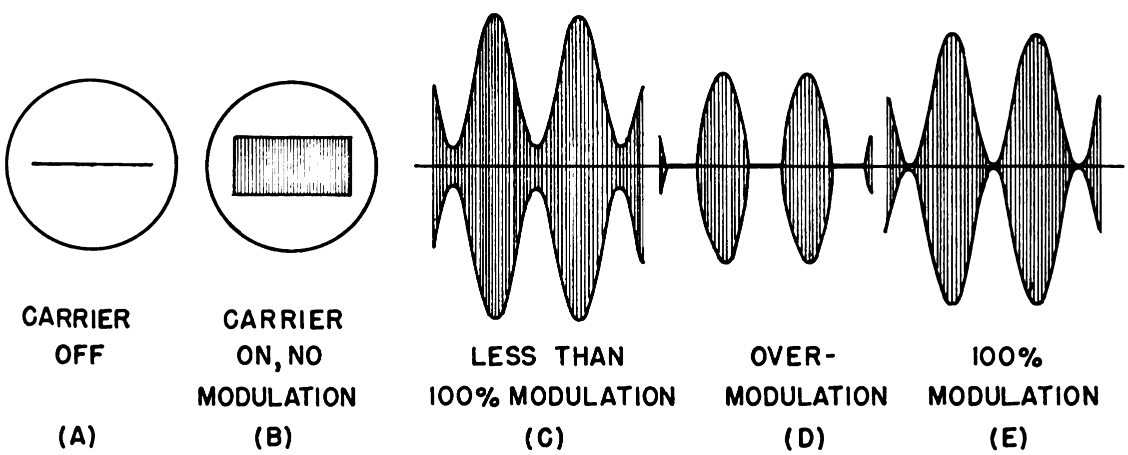


FIGURE 7-3 WAVE PATTERNS FOR MODULATION CHECKING

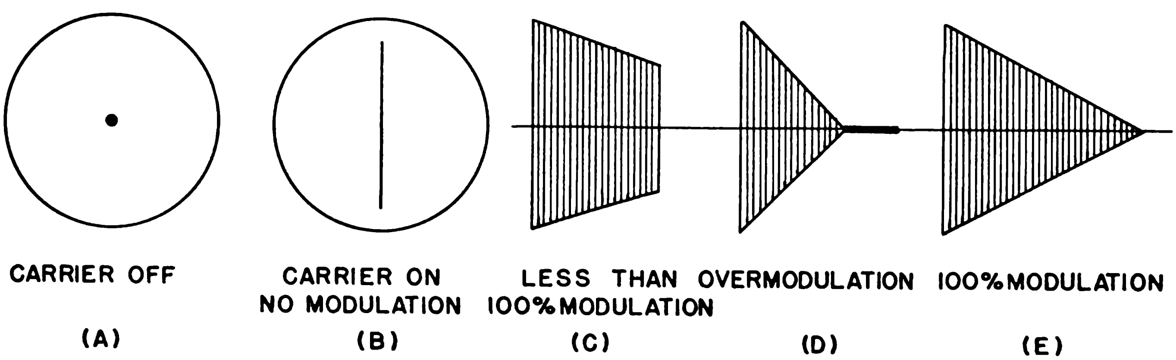
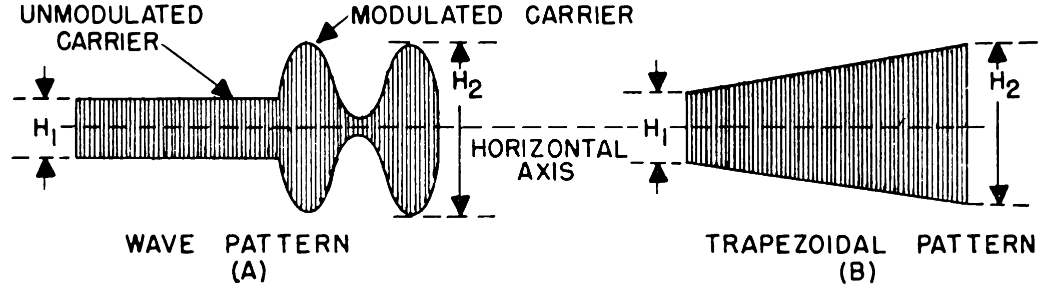


FIGURE 7-4 TRAPEZOIDAL MODULATION PATTERNS



MODULATION PERCENTAGE $= \dfrac{H_2 - H_1}{H_1} \times 100$

PATTERN HEIGHTS H_1 AND H_2 MAY BE MEASURED IN INCHES, CENTIMETERS, OR SIMPLY VERTICAL SCREEN DIVISIONS.

FIGURE 7-5 DETERMINATION OF MODULATION PERCENTAGE FROM OSCILLOSCOPE PATTERNS

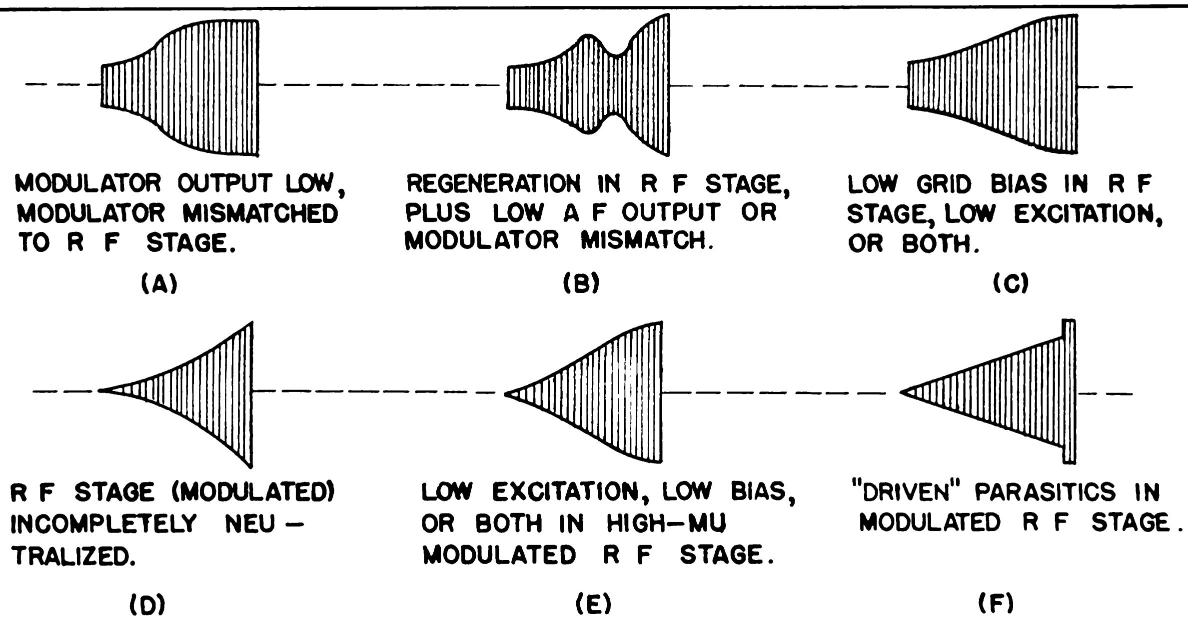


FIGURE 7-6 TRAPEZOIDAL PATTERNS INDICATING VARIOUS TRANSMITTER FAULTS

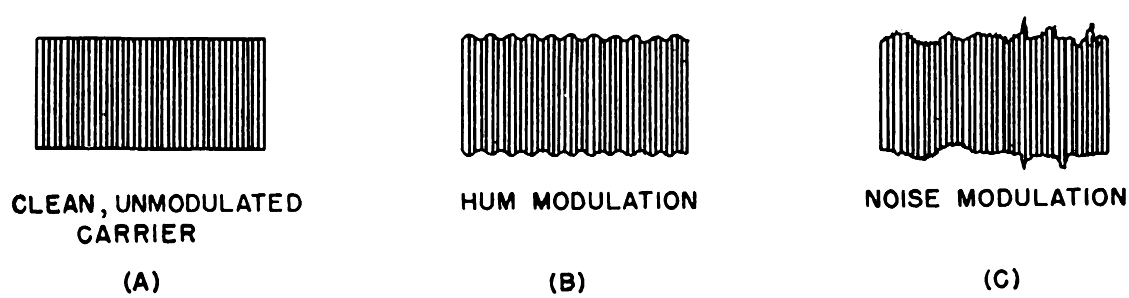


FIGURE 7-7 EXTRANEOUS MODULATION ON R F CARRIER

shown in Figure 7-4. Figure 7-5(B) gives the method of computing *any* modulation from trapezoidal patterns. Figure 7-6 shows commonly-encountered trapezoidal modulation patterns indicating transmitter troubles of various sorts.

7.3 DETECTING HUM AND NOISE ON CARRIER

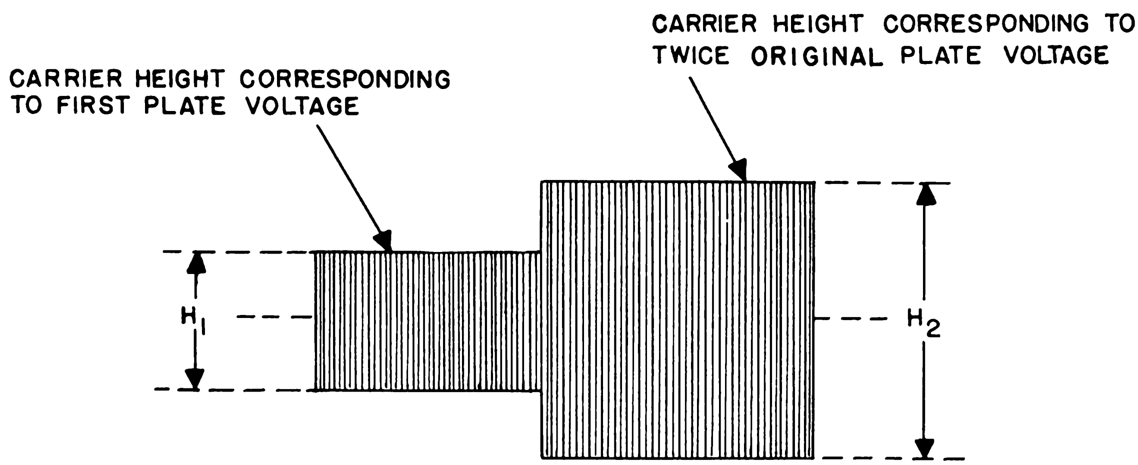
Hum or noise modulation may be detected on the unmodulated carrier of a transmitter by means of an oscilloscope set up as shown in Figure 7-1.

When the carrier is clean, that is, free of hum or noise, the top and bottom edges of the "carrier only" pattern (see Figure 7-7(A)) are flat, sharp and straight. Hum modulation causes a sine-wave ripple to appear on both top and bottom edges (Figure 7-7 (B)). This ripple is usually low. Noise, usually arising in the audio amplifier stages or produced by leaky circuit components or intermittent opens or shorts in any part of the transmitter, causes a ragged modulation to appear on the top and bottom edges of the pattern, as in Figure 7-7(C).

7.4 CHECKING CLASS-C LINEARITY

For best fidelity, the class C rf output amplifier in an AM transmitter must have a linear plate characteristic. That is, if the dc plate voltage of this stage is doubled, the rf output voltage likewise should be double.

This action may be checked with an oscilloscope and the linearity of the final amplifier determined. Set up the oscilloscope as shown in Figure 7-1. A wide band pattern is obtained for the unmodulated carrier (see Figure 7-7(A)). Measure the height of this pattern (Figure 7-8). Double the dc plate voltage of the class-C final amplifier and measure the new pattern height. For best linearity, the second height will be exactly twice the first.



H_1 AND H_2 (HEIGHTS) MAY BE MEASURED IN INCHES, CENTIMETERS, OR VERTICAL SCREEN DIVISIONS.

FOR GOOD LINEARITY, $\frac{H_2}{H_1} = 2$.

FIGURE 7-8 MEASUREMENT OF LINEARITY OF CLASS-C R F AMPLIFIER FROM OSCILLOSCOPE PATTERN

CHAPTER VIII

MISCELLANEOUS APPLICATIONS

8.1 FREQUENCY CHECKING WITH CIRCULAR PATTERN

An oscilloscope and a calibrated variable-frequency audio oscillator may be used with great accuracy for the identification of unknown frequencies. Connection of the instruments for frequency measurements are shown in Figure 8-1. Patterns appearing on the screen for various relationships between the unknown frequency and the frequency setting of the audio oscillator are shown in Figure 8-2.

In this application, the sweep oscillator in the oscilloscope is switched off, and sync controls are set at zero. The unknown frequency is applied to the vertical input terminals, and the audio oscillator is connected to the horizontal input terminals. When the oscillator is adjusted exactly to the unknown frequency, a single *stationary* circle or ellipse appears on the screen (see Figure 8-2(A)). When this pattern is obtained, the unknown frequency may be read directly from the oscillator dial. Other frequency relationships are indicated by the patterns shown in Figure 8-2(B) to (G).

8.2 FREQUENCY CHECKING WITH SINE-WAVE PATTERN

If the oscilloscope is set up for sine-wave patterns, a signal of unknown frequency may be applied to the vertical input terminals and the internal linear sweep oscillator frequency adjusted to give a single stationary cycle on the screen. If the fine frequency control of the oscilloscope has been calibrated beforehand, the unknown frequency may be read at this point from the setting of the fine frequency control. Section 8.5 explains calibration of the fine frequency control.

This method of frequency identification will be found to be very convenient, but it does not offer the accuracy of other methods outlined in Sections 8.1, 8.3 and 8.4. The inaccuracies of the system are due largely to the fact that the sawtooth sweep oscillator cannot be expected to possess the accuracy and stability of an external sine-wave audio oscillator. Also, adjustment of the sync amplitude control, necessary to lock the image on the screen, inadvertently shifts the frequency of the sweep oscillator.

8.3 FREQUENCY CHECKING WITH OTHER PATTERNS

In the system of frequency identification described in Section 8.1, when the ratio between unknown and standard frequencies becomes high, counting the loops of the pattern is difficult and apt to introduce inaccuracies. This may be appreciated if the patterns shown in Figure 8-2(D) and 8-2(G) are examined.

A system which is much easier to handle and pro-

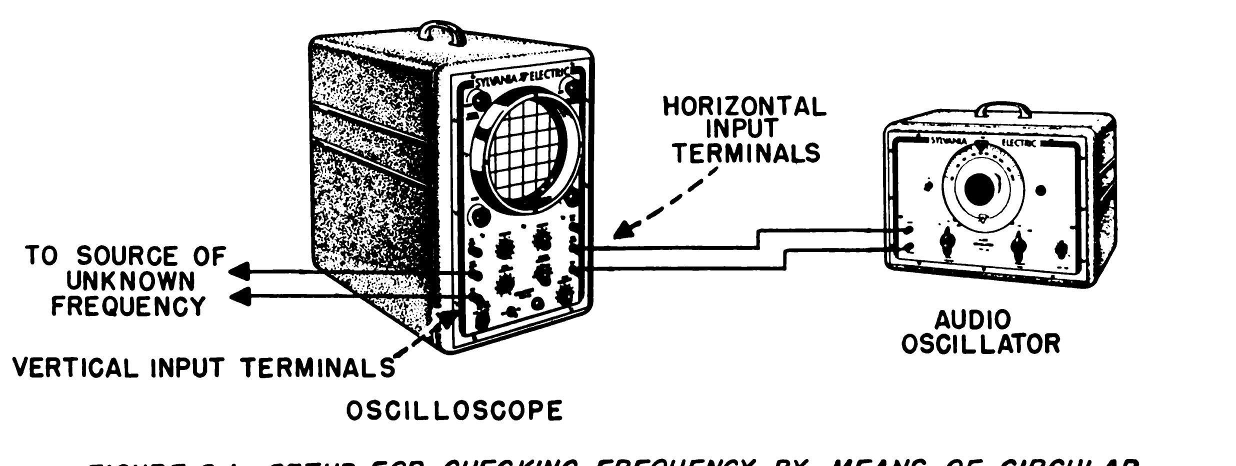


FIGURE 8-1 SETUP FOR CHECKING FREQUENCY BY MEANS OF CIRCULAR (ELLIPTICAL) PATTERN

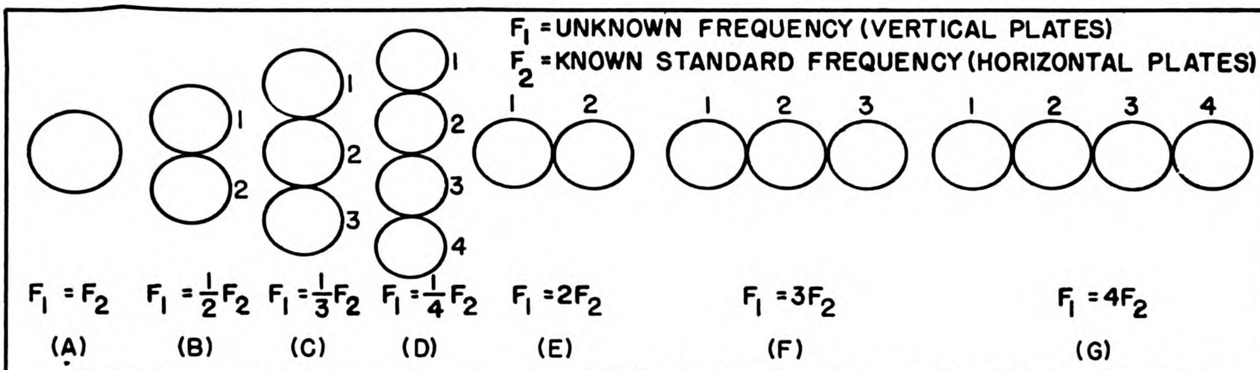


FIGURE 8-2 LISSAJOUS PATTERNS OBTAINED IN FREQUENCY CHECK, USING APPARATUS AND CIRCUIT SHOWN IN FIGURE 8-1

ductive of better accuracy employs *gear-wheel* patterns, such as shown in Figure 8-4. Here, the operator need only to count the small cycles, or gear teeth, in the pattern to obtain the figure whereby the known standard frequency must be multiplied to equal the unknown frequency.

The instrument connections for comparing frequencies by means of gear-wheel patterns are given in Figure 8-3. The internal sweep oscillator of the oscilloscope is switched off for this test. The external capacitor and resistor form a phase-splitting network which produces a circular pattern on the screen (when no unknown signal is applied to the circuit), provided the capacitor reactance equals the 5000-ohm resistance—or an ellipse for all other reactance-resistance relationships. When the unknown signal is applied, the circle of ellipse breaks up into cycles or gear teeth. Figure 8-4(A) shows the toothed ellipse, while Figure 8-4(B) and (C) show toothed circles.

The audio oscillator (see Figure 8-3) is employed here as the source of standard, known signal frequencies. The unknown signal is applied, and the oscillator frequency dial is adjusted to obtain a stationary pattern on the screen. The unknown frequency then may be determined by multiplying the oscillator frequency by the number of teeth in the pattern. If the number of teeth is too great for convenient counting, increase the oscillator frequency.

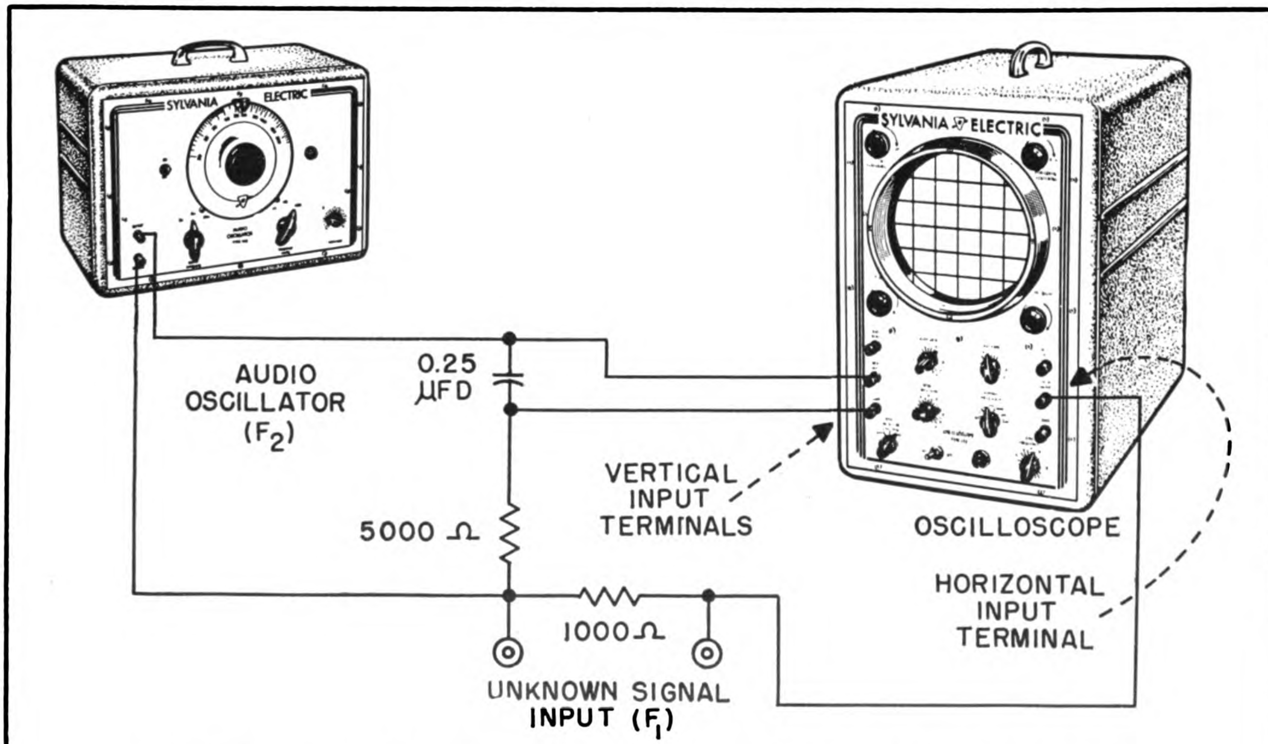


FIGURE 8-3 SETUP FOR COMPARING FREQUENCIES BY MEANS OF GEAR-WHEEL PATTERNS

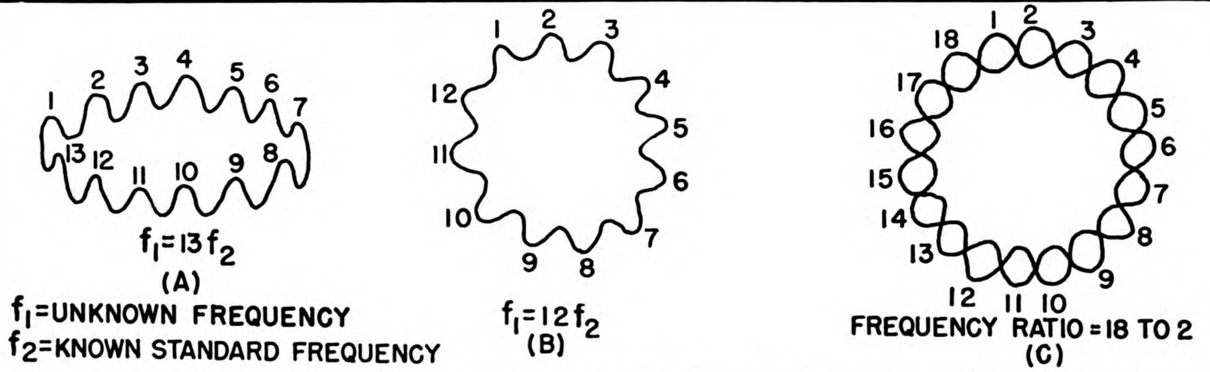


FIGURE 8-4 GEAR-WHEEL FREQUENCY COMPARISON PATTERNS OBTAINED WITH CIRCUIT SHOWN IN FIGURE 8-3

8.4 FREQUENCY CHECKING WITH INTENSITY MODULATION

A variation of the system for comparing frequencies described in Section 8.3 is the interesting *spot-wheel* method. In this system, a spotted-wheel pattern (see Figure 8-6) is obtained. To determine the unknown frequency, the operator simply multiplies the known standard oscillator frequency by the number of spots counted around the circumference of the wheel.

The apparatus setup for the spot-wheel method is shown in Figure 8-5. The internal sweep oscillator of the oscilloscope is switched off. The oscilloscope must have provision for intensity modulation of the electron beam. The Sylvania Oscilloscope Type 132 has this feature, there being an intensity modulation input jack on the rear panel of this instrument.

With the setup shown in Figure 8-5, a circle or ellipse appears on the screen when no unknown signal is applied. The pattern is a circle when the reactance of the external 0.25-µf capacitor equals the 5000-ohm resistance. The pattern is an ellipse for all other reactance-resistance relationships. When the unknown signal is applied, the circle or ellipse is broken up into spots or short lines, depending upon the waveform of the unknown signal. The minimum intensity should be used in this application in order to emphasize the spots and blanked-out segments. It is very important that the unknown frequency voltage applied to the Z axis should not exceed ± 2 v peak. To determine the unknown frequency, multiply the oscillator frequency by the number of spots or lines counted around the wheel circumference. If the number of spots or lines is too large for accurate counting, or if it becomes difficult to "lock" the wheel pattern, increase the oscillator frequency to obtain a lesser number.

8.5 CALIBRATION OF FINE FREQUENCY CONTROL

In order to use the frequency identification method outlined in Section 8.2, it is necessary first to calibrate

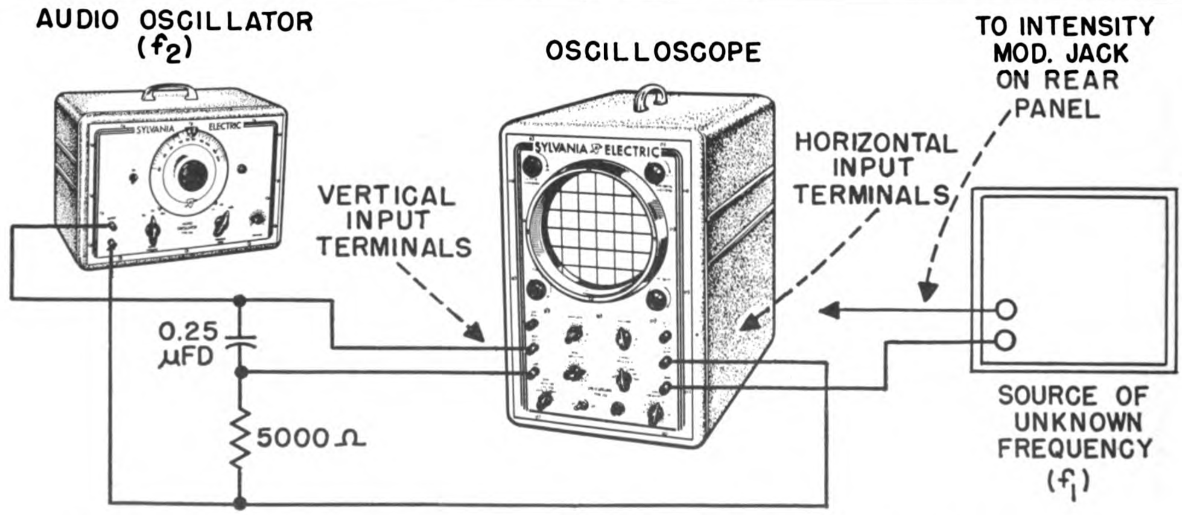


FIGURE 8-5 SETUP FOR COMPARING FREQUENCIES BY MEANS OF SPOT-WHEEL PATTERN

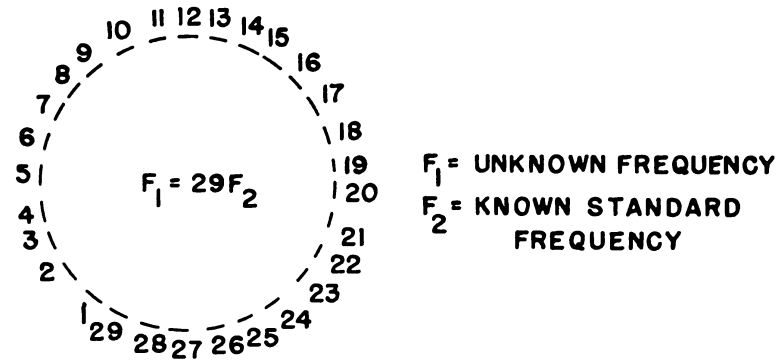


FIGURE 8-6 SPOT-WHEEL PATTERN OBTAINED WITH CIRCUIT SHOWN IN FIGURE 8-5

the fine frequency control of the oscilloscope for each setting of the coarse frequency control.

This calibration may be made by means of an external variable-frequency audio oscillator connected to the vertical input terminals of the oscilloscope. The sync switch is thrown to INTERNAL, sync amplitude control at about ¾ maximum, and horizontal gain control set for wide image. For each setting of the coarse frequency control, the fine frequency control must be set successively to each of its dial readings and the frequency discovered by varying the audio oscillator frequency until a single, *stationary* cycle is seen on the screen. At this point, the sweep oscillator (fine frequency control) frequency may be determined by reading directly from the audio oscillator dial. A chart may be prepared to show the frequencies corresponding to all settings of the fine frequency and coarse frequency controls.

8.6 CHECKING PHASE RELATIONSHIPS

If two sine-wave alternating voltages which have the same frequency are applied simultaneously to the horizontal and vertical deflecting plates of the cathode ray tube, the pattern seen on the screen will show the phase relationship between the two voltages. The two voltages may be produced by separate devices, such as two oscillators, or they may be taken from separate points in the same circuit.

Figure 8-7 shows the simple arrangement of the oscilloscope for phase tests. In this application do not use either the horizontal or vertical amplifier, since both oscilloscope amplifiers introduce some phase shift. Use the DIRECT horizontal and vertical inputs. Switch off the sweep oscillator during this test.

Figure 8-8 shows typical patterns seen on the screen when two ac signals are compared. When both signals have the same amplitude, the patterns are symmetrical, as shown in Figure 8-8. But if the signal applied to the vertical plates is the larger of the two, the pattern will be stretched from top to bottom. Similarly, if the signal applied to the horizontal plates is the larger of the two, the pattern will be stretched from side to side.

8.7 CHECKING PHASE INVERTER ACTION

Figure 8-9 shows a typical phase inverter circuit in an audio amplifier, with points A, B, and C labeled for connection to an oscilloscope. The phase inverter takes the place of a coupling transformer in the am-

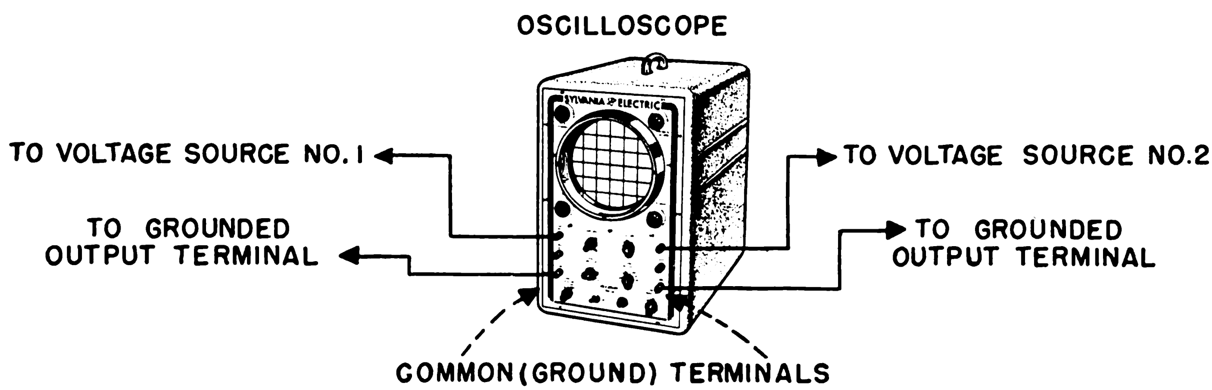


FIGURE 8-7 CONNECTIONS FOR PHASE CHECKING

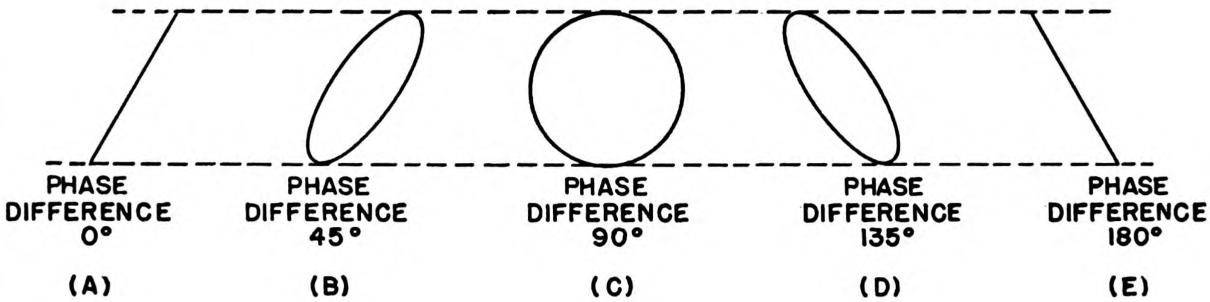


FIGURE 8-8 TYPICAL PHASE-DIFFERENCE PATTERNS

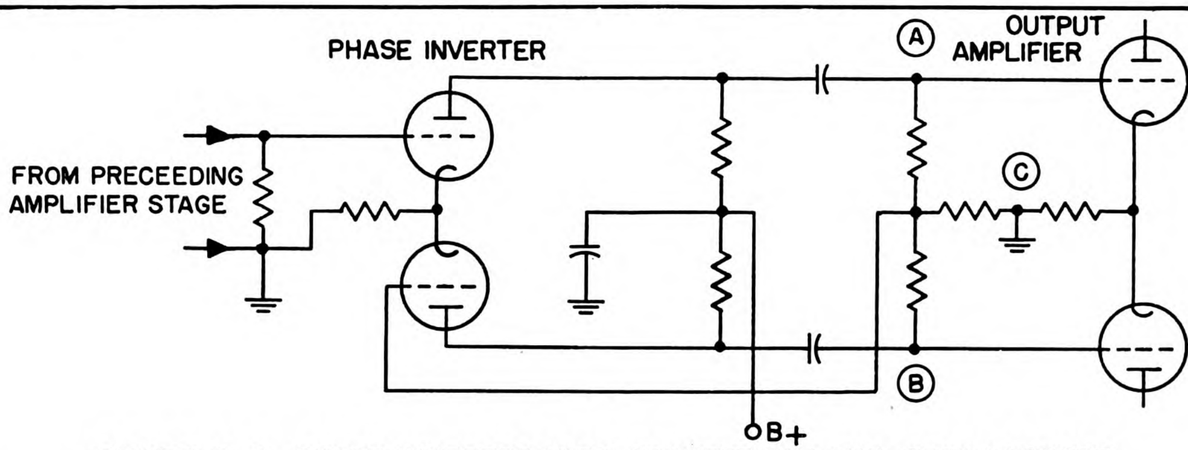


FIGURE 8-9 PHASE INVERTER, WITH CONNECTIONS FOR OSCILLOSCOPE

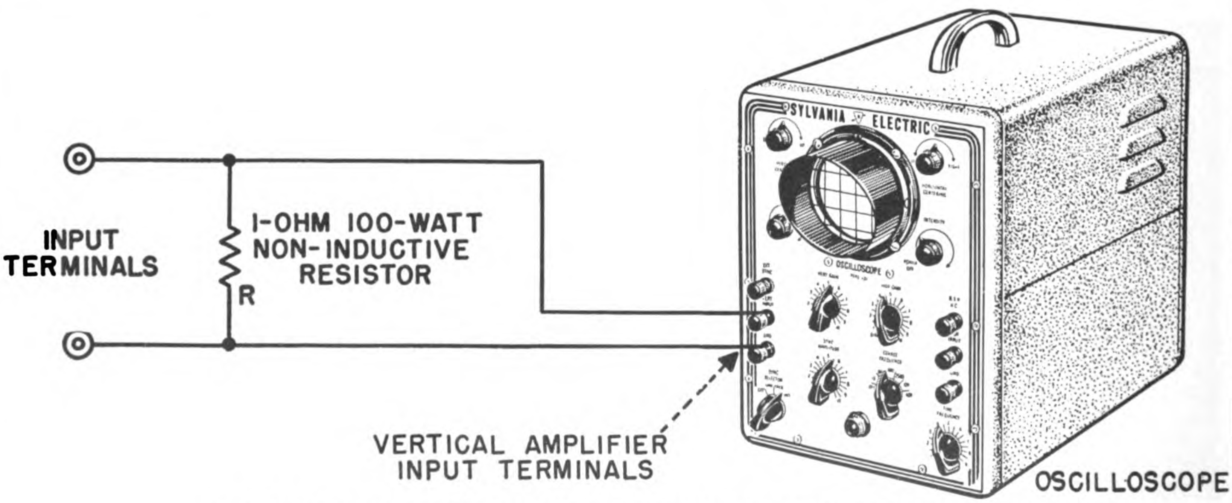


FIGURE 8-10 CONNECTIONS FOR CURRENT MEASUREMENT

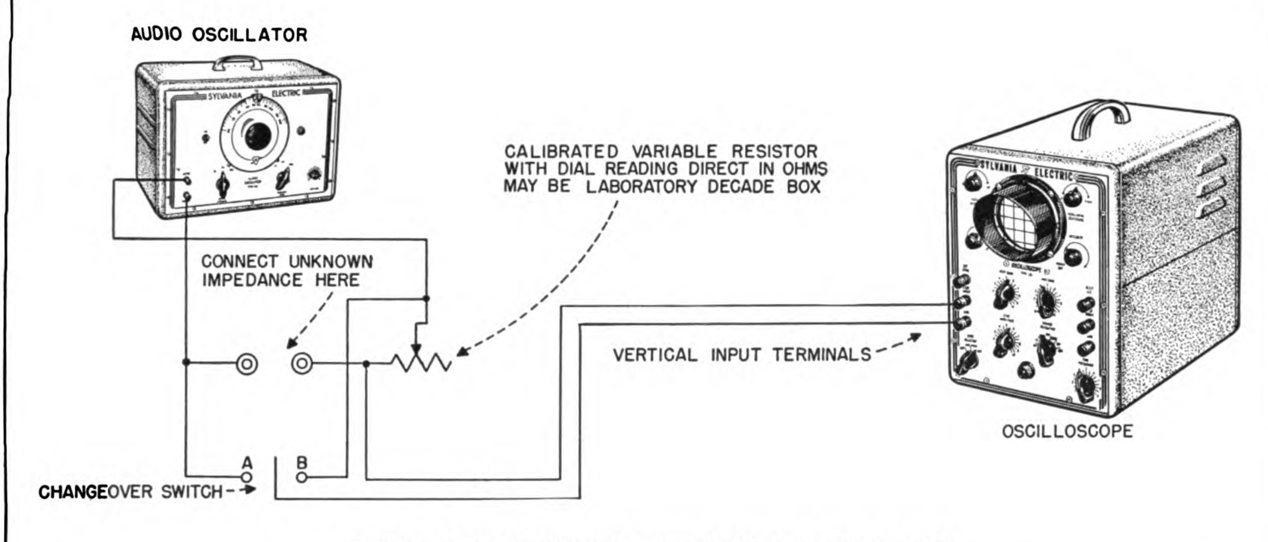


FIGURE 8-11 SETUP FOR IMPEDANCE MEASUREMENT

plifier circuit. If it is working correctly, the grids of the two output tubes are driven 180° out of phase, with respect to each other, when a signal is applied to the input terminals of the amplifier. To check action of the phase inverter:

(1) Connect COMMON (GROUND) input terminal of oscilloscope to point C.

(2) Connect VERTICAL input terminal to point A.

(3) Connect HORIZONTAL input to point B.

(4) Switch oscilloscope for DIRECT input to both sets of deflecting plates. Do not use horizontal and vertical amplifiers.

(5) Switch-off sweep oscillator in oscilloscope.

(6) Apply audio signal (400 or 1000 cycles) to input terminals of amplifier and note pattern on oscilloscope screen.

(7) When phase inverter is working correctly, the 180° pattern shown in Figure 8-8(E) will be obtained.

8.8 CURRENT MEASUREMENT WITH OSCILLOSCOPE

Figure 8-10 shows the simple circuit for oscilloscopic measurement of alternating current (milliamperes and amperes). In this application, the oscilloscope is operated as a voltmeter to check the voltage drop produced across a non-inductive resistor, R, by

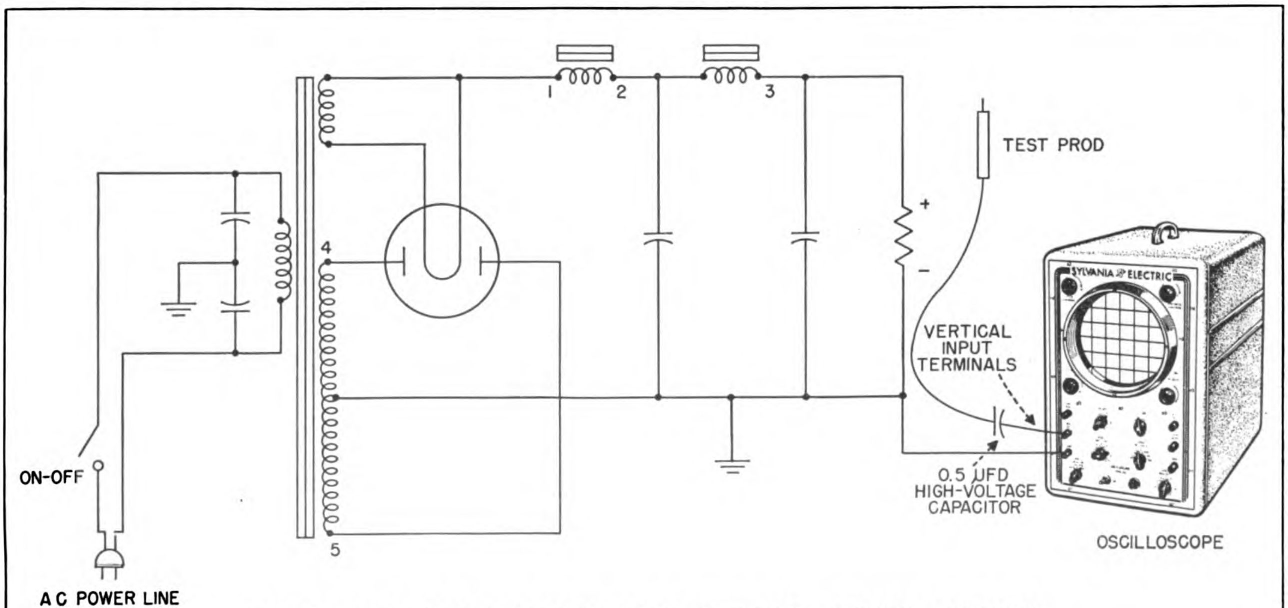


FIGURE 8-12 ARRANGEMENT FOR TESTING POWER SUPPLY

the unknown current. The unknown current (I) equals E/R, where E is the voltage shown by the oscilloscope. If R is made 1 ohm, then I = E. When the power rating of the resistor is 100 watts, up to 10 amperes may be measured.. The oscilloscope screen and vertical gain control must be calibrated for voltage according to the instructions given in Sections 4.6 and 4.7. When the circuit of Figure 8-10 is employed, the current values may be read directly from the oscilloscope screen and vertical gain control setting.

8.9 IMPEDANCE MEASUREMENT

The apparatus setup for impedance measurements is shown in Figure 8-11. This is a convenient arrangement for measuring the impedance directly of such components as coils, capacitors, speaker voice coils, transformer windings, and combinations of resistance, capacitance and inductance.

The calibrated variable resistor is provided with a dial reading direct in ohms. If desired, this resistor may be one or more laboratory decade resistance boxes. The oscilloscope is set up for sine-wave patterns or for a straight vertical-line trace. The oscilloscope functions as a high-impedance electronic ac voltmeter which may be switched across the unknown impedance when the changeover switch is in position A, or across the known resistance when the switch is in position B.

The unknown impedance is connected to the two terminals so labeled in Figure 8-11. The changeover switch is thrown to position B, a trial setting made of the resistor, and the oscillator output control and vertical gain control are adjusted for a pattern of good height on the oscilloscope screen. The changeover switch then is thrown to position A, noting whether pattern height shifts. If height shifts, throw switch back to B, reset the variable resistor to a new value, and throw switch back to A. Without changing the oscillator output or the setting of the vertical gain control, work back and forth between positions A and B of the changeover switch, carefully adjusting the resistor until no change is noticed in the pattern height as the switch is thrown back and forth. At that point, the resistance equals the unknown impedance, and the impedance value may be read directly from the dial of the variable resistor.

With this arrangement, impedance may be checked at any desired frequency within the range of the audio oscillator simply by setting the oscillator beforehand to the desired frequency. This is a particular advantage, since some audio components have their impedance values given for 400 cycles, while others are rated at 1000 cycles.

8.10 AC POWER SUPPLY TESTS

The oscilloscope is extremely useful for measuring peak voltages across filter capacitors in ac power supply units. A typical choke input-type power supply is shown in Figure 8-12 with an oscilloscope arranged for testing in this circuit. Waveform, as well as peak amplitude, may be observed with this setup.

The oscilloscope is set for either sine-wave pattern (if the operator is interested in waveform) or for straight-line vertical trace. The screen and vertical gain control must be calibrated in voltage (see Sections 4.6 and 4.7) *with the external 0.5-μf dc blocking capacitor in place.*

The high vertical input terminal of the oscilloscope must be provided with a well-insulated test prod for connection to the various numbered circuit points. When the prod is at point 1, oscilloscope shows waveform and amplitude of voltage at input of first filter choke; at 2, waveform and amplitude of voltage across first filter capacitor; at 3, waveform and amplitude of voltage at output of second filter choke and across second filter capacitor. Equal peak voltages should be observed when the prod is touched alternately to 4 and 5. Any difference in amplitude indicates unbalance between the two halves of the power transformer secondary winding.

Effectiveness of the filter sections can be noted by observing the waveform at points 1, 2 and 3. In this

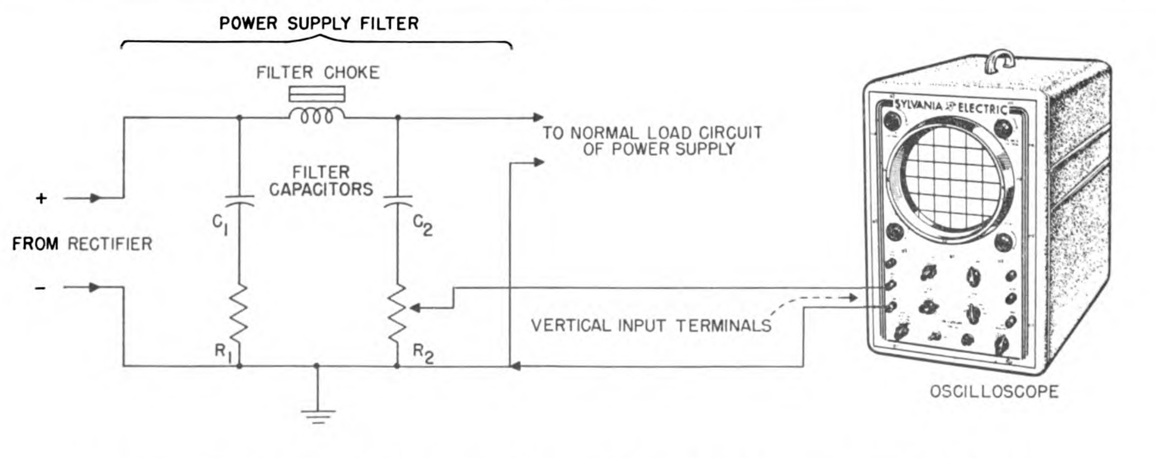


FIGURE 8-13 CONNECTIONS FOR CHECKING RIPPLE CURRENT IN FILTER CAPACITORS

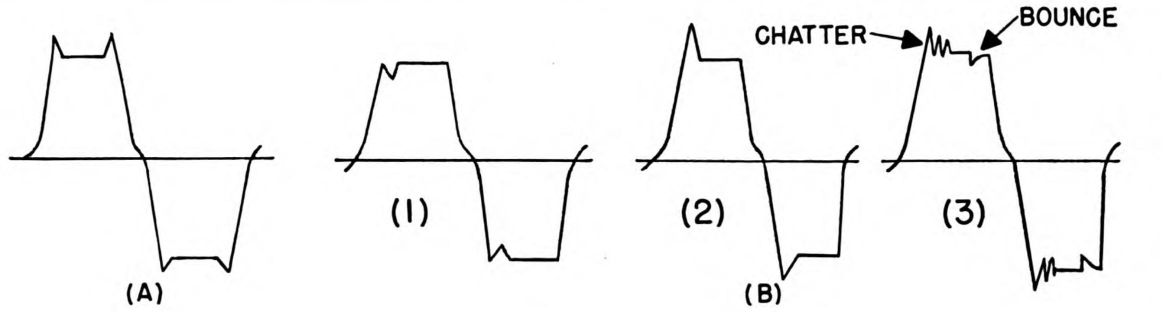


FIGURE 8-14 AUTO RADIO VIBRATOR WAVEFORMS, AS OBSERVED ON OSCILLOSCOPE SCREEN

way, defective chokes and/or capacitors may be isolated.

8.11 CHECKING RIPPLE CURRENT IN FILTER CAPACITORS

The peak value of ripple current in filter capacitors is an important characteristic which must be checked in any complete study of power supply behavior. The oscilloscope is the best instrument to use for checking peak capacitor current since it shows not only the peak current value but also the wave shape of the ripple current.

Figure 8-13 shows the connections which must be made between a power supply and oscilloscope in order to check capacitor peak current. Connect a 1-ohm resistor (see R_1 and R_2) in series with each capacitor to be checked. Connect the vertical input terminals of the oscilloscope across the resistor, as shown in Figure 8-13.

Set the oscilloscope controls for voltage measurements with sine-wave patterns, as described in Section 4.4. Use the vertical amplifier of the oscilloscope in this test. Read the peak voltage drop across the resistor R_1 or R_2 (see Figure 8-13), by means of the oscilloscope screen calibration and vertical gain control calibration.

To determine the peak current, this peak voltage value must be divided by the resistance of R_1 or R_2. But since the resistance is 1 ohm, no division is required. Thus, a peak voltage of 0.05 v across resistor R_2 indicates a peak current of 0.05 ampere (50 milliamperes) flowing through capacitor C_2. Similarly, a peak voltage of 0.021 v across resistor R_1 indicates a peak current of 21 ma flowing through filter capacitor C_1.

8.12 CHECKING PEAK CURRENT IN RECTIFIERS

Peak current in *rectifier tubes* may be checked in the same manner described in Section 8.11, except that the 1-ohm test resistor is connected in series with the plate of the rectifier tube. Before attempting to make this test, connect an external 0.5-µf capacitor in series with each of the vertical input terminals of the oscilloscope to protect the instrument from the rectifier voltage, and make a voltage calibration of the oscilloscope screen and vertical gain control with these capacitors connected. Each capacitor must be

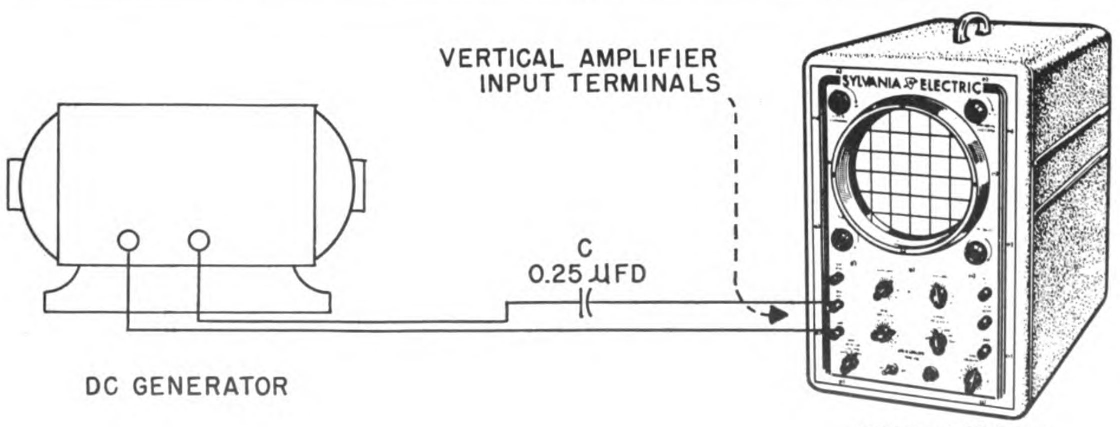


FIGURE 8-15 CONNECTIONS FOR CHECKING RIPPLE OF DC GENERATOR

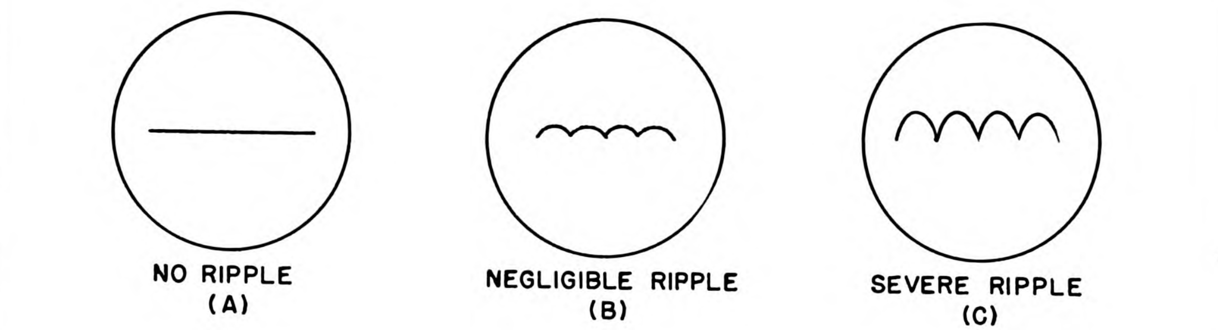


FIGURE 8-16 GENERATOR RIPPLE PATTERNS

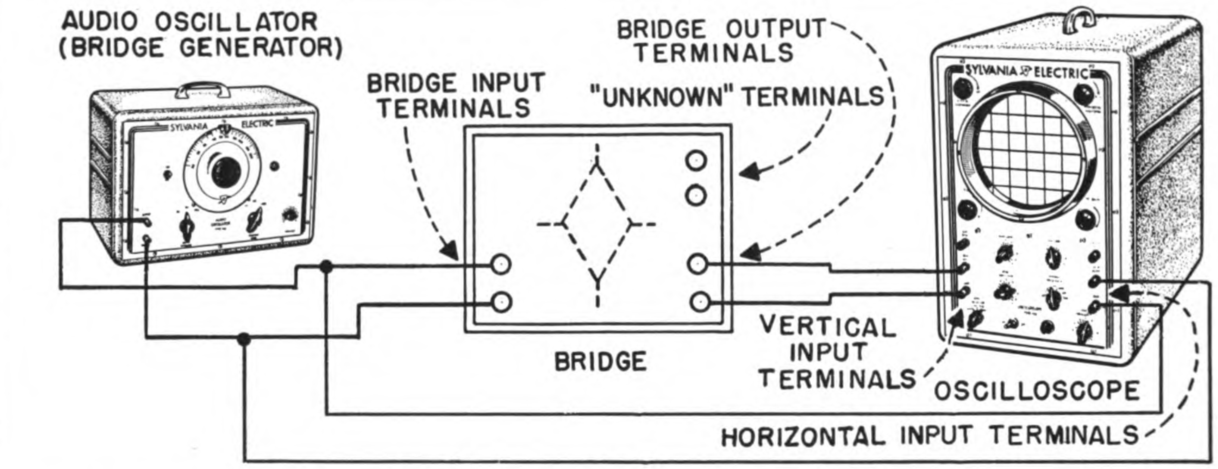


FIGURE 8-17 CONNECTIONS FOR OSCILLOSCOPE AS BRIDGE NULL DETECTOR

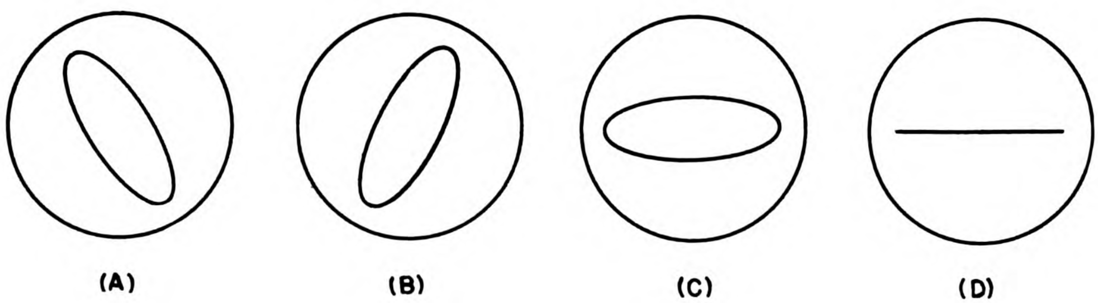


FIGURE 8-18 NULL DETECTOR PATTERNS

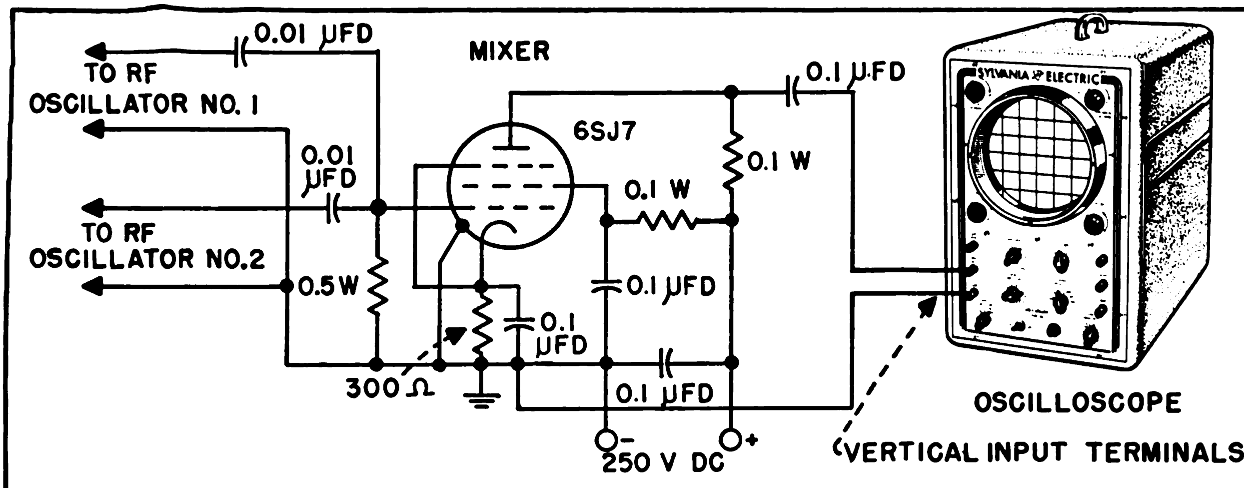


FIGURE 8-19 CONNECTIONS FOR FREQUENCY COMPARISON

rated at twice the ac voltage applied to the rectifier tube. DANGER! DO NOT TOUCH THE METAL CASE OF THE OSCILLOSCOPE OR ANY SWITCH OR OTHER METALLIC DEVICE ATTACHED TO THE CASE OR PANEL.

8.13 AUTO RADIO VIBRATOR TESTS

The cathode ray oscilloscope enables the radio serviceman to observe auto radio vibrators while they are in operation and, from these observations, to determine faults in these units.

In order to make the vibrator test, the vertical input terminals of the oscilloscope must be connected across the entire primary of the auto radio power supply. The receiver must be in operation, that is, switched-on. The oscilloscope is set for sine-wave patterns, sync switch thrown to INTERNAL, and sync amplitude control advanced to lock image on screen. Oscilloscope frequency controls are set to give a single "cycle" on the screen. Several patterns observed with vibrators in operation are shown in Figure 8-14.

Figure 8-14(A) is the correct waveform for a tubeless, non-synchronous vibrator operating in the receiver and adjusted properly. Waveform (1) in figure 8-14(B) shows the small peaks on each half-cycle caused by using too small a buffer capacitance. Waveform (2) in the same figure represents the same vibrator operating with too small a capacitor, but with the power supply load removed. Waveform (3) shows the appearance of pattern resulting from a vibrator in which considerable bounce and chatter are present.

8.14 CHECKING DC GENERATOR RIPPLE

The oscilloscope is invaluable for studying the effectiveness or commutator and filter action in dc generators. When commutation and filtration are efficient, little or no ripple is present in the output voltage. The oscilloscope shows the actual ripple amplitude, as well as its presenee.

Figure 8-15 shows connections for generator ripple measurements. The generator is connected to the vertical amplifier input terminals of the oscilloscope through a 0.25-µf fixed capacitor rated at twice the

FIGURE 8-20 FREQUENCY COMPARISON PATTERNS

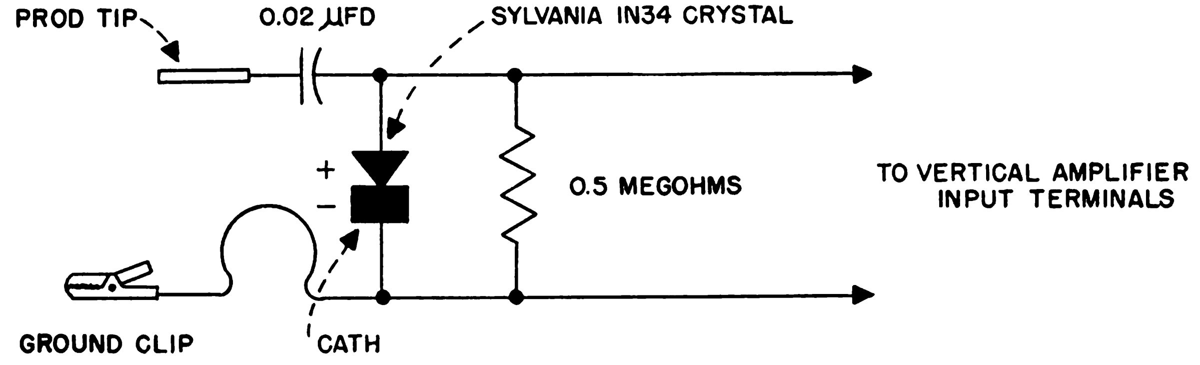


FIGURE 8-21 RF EXPLORING PROBE FOR SIGNAL TRACING

generator output voltage. The oscilloscope is adjusted for sine-wave patterns.

Figure 8-16 shows typical generator ripple patterns. When no ripple at all is present in the generator output voltage, the pattern is the normal straight horizontal line trace, as shown in Figure 8-16(A). When the ripple is small, the height of the ripple peaks will be low (see Figure 8-16(B)). Large peak amplitudes, such as shown in Figure 8-16(C), indicate severe ripple. The actual peak voltage amplitude (value) may be read from the oscilloscope screen, provided the latter has been voltage-calibrated according to the directions given in Sections 4.6 and 4.7.

8.15 USE OF THE OSCILLOSCOPE AS BRIDGE NULL DETECTOR

The cathode ray oscilloscope makes a sensitive null detector for impedance bridges of the ac type. This type of null detector permits separate reactive and resistive balances to be made with accuracy. Connections for an oscilloscope-type null detector are shown in Figure 8-17. Null detector patterns are shown in Figure 8-18.

When used as a bridge null detector, the internal sweep oscillator is switched-off. The vertical gain control is set for good pattern height, and the horizontal gain control for good pattern width. When the bridge is unbalanced, one of the patterns shown in Figure 8-18 (A) and (B) will be seen on the screen. One tilted ellipse indicates unbalance below the null point; the other, unbalance above the null point. As the reactive balance of the bridge is completed, the ellipse rolls around and rests horizontally, as shown in Figure 8-18(C). When the resistive balance of the bridge is completed, the ellipse closes up to form a straight, horizontal line, as shown in Figure 8-18(D).

8.16 USE OF OSCILLOSCOPE AS ZERO BEAT INDICATOR

When the frequencies of two rf oscillators are to be compared, a cathode ray oscilloscope may be employed as an accurate, sensitive zero beat indicator, the oscilloscope has no equal. An example of this application is the process of setting the frequency of a variable frequency or adjustable crystal oscillator to that of a crystal frequency standard.

Circuit connections for frequency comparison are shown in Figure 8-19. Rf output voltages from the two oscillators are capacitively-coupled to the control grid of a pentode mixer tube. The plate output circuit of the mixer is connected to the vertical amplifier input terminals of the oscilloscope. When the frequency of one of the oscillators differs from that of the other, an audio-frequency beat note is set up, giving a pattern on the oscilloscope screen similar to that shown in Figure 8-20(A). But when the two oscillator frequencies are exactly the same, zero beat occurs, and the straight-line trace (see Figure 8-20(B)) is obtained. At exact zero beat, the line is perfectly straight and smooth. An extremely sharp

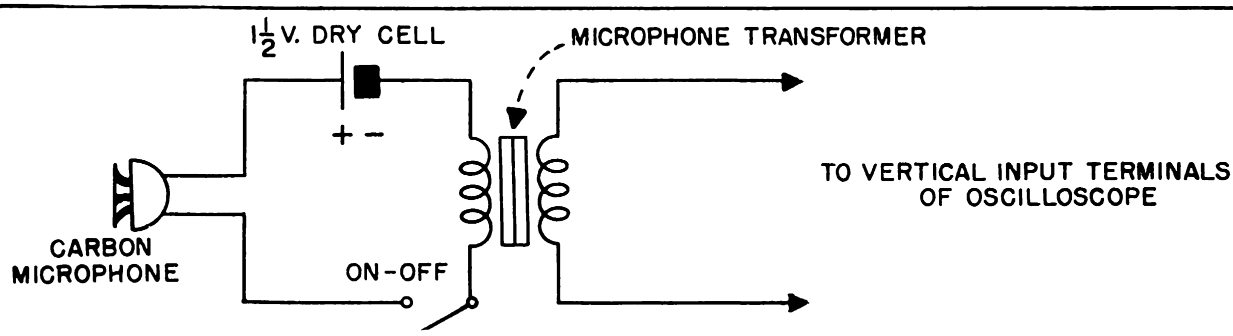


FIGURE 8-22 MICROPHONE CONNECTIONS FOR SPEECH-MUSIC WAVEFORMS

zero beat indication is obtained by adjusting one of the oscillators for this straight-line pattern.

For the zero beat test, prepare the oscilloscope in the following manner:

(1) Set coarse and fine frequency controls to approximately 100 cycles.
(2) Set sync switch to INTERNAL.
(3) Set sync amplitude control at about ½ maximum.
(4) Set horizontal gain control for long straight-line trace.
(5) Set vertical gain control for desired pattern height when beat note pattern (Figure 8-20(A)) is obtained.

8.17 EXPLORING PROBE FOR RF SIGNAL TRACING

When the oscilloscope is to be used to trace a radio-frequency signal through a radio receiver circuit, some form of peak diode rectifier probe must be used ahead of the vertical amplifier. Figure 8-21 shows the schematic of a crystal-type probe which is satisfactory for this application and is useful well into the ultra-high-frequency spectrum. All of the components of the crystal probe may be fitted into the handle of a large-size test prod.

When using the crystal probe and oscilloscope, apply a *modulated* rf signal to the antenna and ground terminals of the receiver under test. Prepare the oscilloscope for sine-wave patterns, and set the coarse and fine frequency controls for a sweep frequency equal to 4 or 5 times the signal modulating frequency.

The ground clip of the probe is attached to the receiver chassis (B-minus) and the prod tip is touched successively to the input and output terminals of each stage, working through the receiver from antenna to loudspeaker. The signal will appear as a string of cycles on the screen. Loss of the signal at any point in the circuit will be indicated by a reduction to the horizontal line trace. Amplification is indicated by an increase in pattern height.

8.18 DEMONSTRATION OF SPEECH WAVEFORMS

Speech or music waveforms may be shown directly on the oscilloscope screen. For this purpose, a microphone will be required. The Sylvania Type 132 Seven-Inch Oscilloscope has sufficient vertical amplifier gain to give speech and music patterns directly when a diaphram-type crystal microphone is connected to its vertical input terminals. Other oscilloscopes may be used in this manner, with crystal microphones, provided sufficient external pre-amplification is introduced. A carbon microphone may be connected in the manner shown in Figure 8-22. For reproduction of waveforms directly from a radio receiver, connect the vertical amplifier input terminals across the loudspeaker voice coil.

When preparing to observe voice or music waveform patterns, set the sync switch in the oscilloscope to INTERNAL, set sync amplitude control to about ½ maximum, set sweep oscillator frequency to about 75 cycles, and set horizontal gain control for long, straight horizontal-line trace. While observing waveform patterns, set sync amplitude control to prevent pattern from drifting across the screen, and set the vertical gain control for the desired pattern height.

8.19 ELECTRONIC SWITCH

Occasionally, it is desirable to view two or more separate signal voltage patterns simultaneously on the oscilloscope screen. There is available for this purpose an external instrument known as an *electronic switch*. The two signals to be studied are applied to the separate pairs of input terminals of the electronic switch. The output of the electronic switch is connected to the vertical input terminals of the oscilloscope. Action of the instrument is to switch onto the oscilloscope vertical input terminals quickly (by means of an electronic circuit) first a part of one signal and then a part of the other. The two signals accordingly are constructed on the screen in tiny segments or pieces, but at such a high rate of speed and with such detail that the eye sees two complete waveforms in proper relation to each other.

This device enables the operator to study two or more separate phenomena which are related to each other. An example is the reproduction of an alternating voltage and corresponding alternating current so as to show phase relation between the two.